TECHNOLOGY QUARTERLY.

EDITED BY JAMES P. MUNROE.

VOL. III. AUGUST, 1890. No. 3.

COMMEMORATIVE ADDRESS TO THE CLASS OF 1890.

(DELIVERED ON GRADUATION DAY.)

BY AUGUSTUS LOWELL, ESQ., MEMBER OF THE CORPORATION.

GENTLEMEN AND LADIES, — Twenty-five years have passed since this building was finished and the Institute of Technology was opened, upon a very modest scale and with a very small number of scholars; but the germ was there, and its rapid growth has come from allowing the school to develop by a process of evolution which has accommodated its teaching gradually and surely to the wants of the age, until, although far from perfect, it is to-day in completeness and comprehensiveness of technical instruction unsurpassed, if not unrivalled, by any institution of its kind.

The term "Technology" was given it by Dr. Jacob Bigelow, one of its earliest advocates, to represent a new departure in the history of instruction. Previous to this attempt, science had been taught as other branches of polite learning, by the university method, with little profit to the ordinary student; while those who made it their serious study prepared to devote their lives to its service, with no thought of applying it to the affairs of life. Science, pursued for its own sake, had little concern for the demands of trade. Any such partnership was beneath its dignity, and justly so. A great change was approaching, however, in the industries of the country. New fields of labor were to be opened up, based upon the discoveries of science and the inventions to which these had given rise, and a class of men would be needed to conduct these new industries for whose instruction no provision had been made in the established systems of education. To meet this want was the

aim of the founder of this school, Professor William B. Rogers. Himself a student of pure science and eminent in many of its branches, but gifted with a rare power rightly to interpret the coming movement, he threw himself enthusiastically into the work.

Professor Rogers was a native of Virginia. He had long been the Director of its Geological Survey, and Professor of Chemistry and Physics in its great University, but he had married here and had lately come to Boston to make it his home. To his high reputation as a scientist he added a rare power of lucid explanation, which enabled him to command the attention of all who listened to him, even when discussing the most abstruse subjects; and so simple and engaging was his manner that the fascination he exerted over all classes of men was irresistible. With these qualities he gathered about him a miscellaneous collection of persons distinguished in their several branches of business, but with little scientific knowledge or training. To them he explained the advantage which his science could bring to their pursuits, and invoked their public spirit to enable him to confer upon the community the inestimable blessing of such a school as he had conceived. Upon these men he relied for such advice and assistance in practical matters as he required, but the conception was his own, and for many years he not only planned, but carried on the work, supplementing the instruction, where needful, out of the fund of his own great knowledge and acquirements. It is not too much to say, not only that but for him would no such school have been founded, at least not at that time, but that it would have been impossible, with such a staff and such appliances as he had at command, to have held it together, had he not been endowed with so remarkable a talent for imparting the vast knowledge he possessed, and gifted with a power of sympathy and enthusiasm which affected all who approached him.

Having secured the interest of this knot of followers, Professor Rogers's next step was to obtain from the Legislature a charter and a grant of land. These were given in April, 1861, upon condition that fifty thousand dollars should be raised by private subscription to erect a building. The necessary sum was secured through the generous gifts of Dr. Walker and Mr. Huntington. The time, however, was not favorable to such an undertaking. The guns of Fort Sumter were still echoing in the public ear, and the demands upon the time and means of our citizens, and upon their interest and energies in the struggle for the maintenance of the Union, left little leisure or thought for other objects. The organization of the school was doubtless also hampered by the strangeness of the project, and the

incredulity of the public as to the demand for such instruction. It was not to be expected that it should at once meet with such public recognition as to secure for it a proper organization and equipment. The project was novel, and as it had been started by the foresight and public spirit of a few individuals, it must be carried on by them at their own expense and by their own exertions until the public mind should have become educated to appreciate the service it was prepared to render. It was clearly a case where the supply must be expected to create the demand. To-day, after the Institute of Technology has been sending its young men out into the world for a quarter of a century, trained to apply the principles of science to the exigencies of the useful arts, there is a tenfold greater demand for its graduates than before such a supply existed.

The close of the civil war found the people of this country ripe for rapid development. The excitement and bustle of war were to be replaced by such an exhibition of national energy in the peaceful arts as the world had never before witnessed. Great inventions, due to the scientific progress of the past fifty years, were crowding upon us. Hereafter entirely new classes of activity were to appear, and the youth of the country, in order to take their place in the coming change, must be specially equipped for the work.

In February, 1865, the school was opened with 27 scholars; the following year there were 72, and from this the number rose rapidly, until, in 1872, it had reached 348. Then came the financial crisis, with the loss of credit, depression of industry, and reduction of private incomes, and the effect of these upon the school was most disastrous. The number of students fell in three years to little more than one half what it had been in 1872, and this was followed by a forced reduction of expenditures, dismissal of valued instructors and a call upon those who remained to do so at a serious reduction in their salaries. The retrenchments rendered necessary at this time came near destroying the Institute of Technology. It had few graduates to speak for it, and they were young men, occupying subordinate positions. Its friends were almost entirely confined to Boston, and some of these began to distrust the enterprise which they had assisted in founding, and more than one meeting of the Corporation was held which came near resulting in the abandonment of the whole undertaking.

The excellent work of its earlier days of poverty and depression and the reputation of its graduates saved it. With the revival of business prospects in 1879 dawned a new era of prosperity for the school. Again the number of scholars began to increase. In 1880 it was

200, and from that time it has steadily grown, until now it has reached 900, and this with no lowering of the standard of scholarship either for admission or graduation. Nine hundred students, ninety permanent instructors, and eleven separate courses, each comprising many branches of instruction, mark the point we have reached to-day. Truly a wonderful result to have been accomplished in so short a time!

Such an unprecedented growth has called for new and ever increasing expenditures by the Corporation, for which the means have never been in hand. Thus the building put up in 1883 cost $300,000, for which there was only $63,000 specially provided. The debt at one time reached $200,000, and but for the courage and generosity of the treasurer, Mr. John Cummings, who put his own name upon its paper, it would have been impossible to go on.

To superintend the work of such an institution demands courage and foresight on the part of its Directors. To recognize the requirements of an enterprise of such rapid growth, and to provide in advance that there may be no hesitation or delay in carrying on the work efficiently, calls for business talent of no mean order; to do all this trusting to the future generosity of an appreciating public requires a reliance upon human generosity, and a blind confidence in the future, which find no place in the ordinary conduct of affairs.

But even with a wise and efficient government, failure must have ensued but for the generous co-operation of the Faculty. Patience, resolution, and self-sacrifice have all been required at the hands of the Professors and teachers, and nobly have they done their part. In the early days of the school the service of these men was a labor of love, but animated by their leader and encouraged by his devotion, they labored on, at every sacrifice, and earned a debt of gratitude from all lovers of higher education, which was the only return they could hope to receive beyond that of their own approval. In the name of the Corporation I desire to put upon record our full appreciation of all that they have done and are still doing for the Institute, and to thank them in our own name and that of the public for their faithfulness and generosity. I know they have a pride in their work. I know that they glory in the Institute; and well they may, for it is above and beyond all things the result of their conscientious and disinterested labors.

The debts of the Institute were paid in 1889, through the generosity of the Commonwealth, and by means of a large private contribution obtained chiefly through the exertions of Mr. William Endicott, Jr. But it was not destined to remain long out of debt. This condition

had hardly been reached before it became evident that the renewed demand for space, due not more to the increase of students than to the rapid specialization of the work of the Institute and the higher and larger types of machinery and apparatus, had rendered the extension of only six years before inadequate.[1] To meet this want the Corporation was compelled last summer to erect a new engineering building on Trinity Place, at a cost of $120,000, of which we owe practically the whole amount to-day. We have now ample space, but there is much that ought to be done, in justice to the teachers especially, which we would gladly do, but cannot for lack of means. The school has grown so fast, that it has been impossible to preserve its due proportions. Much has been pushed aside to meet more urgent wants, and we are sometimes almost tempted to wish that we could pause and put our house in order. But as success means growth, and rapid growth must necessarily be accompanied by much incompleteness of detail, we must accept its conditions, while we triumph in the result of our work, and remember that the school can never be complete until it has ceased to grow, and that then its days of usefulness will be numbered. Great, however, as have been and still are the needs of the Institute, it never has been our habit to proclaim our wants. We have rather chosen to rely upon the recognition of a service well performed, knowing that the public is never slow to appreciate what deserves support, and may be trusted to see that an institution from which it gains so much is not suffered to languish for lack of means.

An institution of learning may make a demand upon public recognition and gratitude because of its good work in training successive classes of young men for usefulness in life, even though it be not an innovator in education, and uses only the old and familiar methods of instruction; but it may acquire a further and larger claim by becoming a leader in its department, by introducing new methods, and opening the way to a better kind of intellectual and professional training.

How the Institute of Technology has dealt with the thousands of young men who have been its pupils since 1865, what it has done for them, what places they now occupy in the industrial system, what services they have rendered to the arts and industries of the country, common fame will tell. Those who would study this matter more

[1] The expense of instruction at a scientific and technical school increases far more rapidly, under an increase in the number of pupils, than at an ordinary classical college. The students must be taught in small sections, often in little groups around a machine or piece of apparatus, under the guidance of an instructor. The cost of delicate instruments and powerful machines, which must always be kept abreast of invention and the best professional practice, is also very great.

carefully will find material in the lists of its graduates and of the places they fill, as told in the annual catalogues.

But in addition to its work in training a certain number of young men for the duties of life, the Institute of Technology has been pre-eminently a leader in education. Its influence has not been confined to what it has done for its own pupils, but has extended as far as its example of advanced scientific and technical instruction has gone.

Almost at the very outset a long step forward was taken in the establishment of a laboratory of general chemistry. Up to that time general chemistry had been taught wholly by means of text-books, or by lectures with experiments by the lecturer. The student's part was only to look and to listen, and learn in this way what he could. It was not until the student was put into the analytical laboratory, and took the retort into his own hand, that he did or discovered anything for himself. Under the inspiration of Professor Rogers and the enterprise and administrative skill of Professor Charles W. Eliot and Professor Frank H. Storer, a laboratory of general chemistry was established, and the pupil from the first day of his chemical studies was set to teach himself. This was no analytical laboratory. It was simply designed as a means of illustrating, emphasizing, and supplementing the instruction of the lecture-room in regard to the nature of chemical action and the characteristics of the principal elements. The student was not told what he should find. He was told to do something and note what occurred. He was thrown upon his own faculties of observation and reflection. He learned to know himself, and to measure his own power, and he acquired ease and accuracy of manipulation by practice. So far as known, this was the first laboratory of such a character set up in the world. Certainly it was the first one instituted in the United States for the instruction of considerable classes of pupils. The publication of Eliot and Storer's Manual, designed for students taking this course, marked an epoch in the history of education.

Another equally important step in scientific education, and one of which the originality is beyond doubt, was taken at about this time in the establishment of a laboratory now known as the Rogers Laboratory of Physics. Under the inspiration of President Rogers the scheme of a laboratory where the student of physics should be set to make observations and conduct measurements for himself, in demonstration and illustration of the physical laws taught in the lecture-room, was carried out with remarkable ability on both the scientific and administrative sides by Professor Edward C. Pickering, now Director of the Harvard Observatory. So complete was Professor Pickering's study

of the needs and capabilities of such a laboratory, so masterly his treatment of it, that it has required only more room and additional apparatus to allow the system he then devised and formulated to be extended successively to classes of fifty, of one hundred, and even of one hundred and fifty students.

In the school year of 1871–72 another forward step in education was taken at the Institute of Technology. Down to that time the instruction in mining engineering and metallurgy had been, here as elsewhere, conducted by means of text-books, lectures, drawing models, and assays of small pinches of ore, supplemented, in the case of the more fortunately situated schools, by occasional visits to mines in actual operation. In the year named a scientific expedition to the Rocky Mountains was undertaken by a large party of students and instructors from the Institute. While in the Colorado mining regions, Professor Runkle conceived the idea of a laboratory which should add to the existing means of instruction in mining and metallurgy the practical treatment by the students of economic quantities of ores. This conception, so fully in the line of the general work of the Institute, was given effect by the purchase in California, before the return of the expedition, of a number of pieces of apparatus suitable for the beginnings of such a laboratory. The apparatus thus obtained was set up by Mr. Robert H. Richards, then instructor, and now for many years Professor of Mining Engineering.

From these small beginnings made under Professor Richards's care it has grown steadily to this day. It was the first proper metallurgical laboratory devoted to the purposes of instruction in the world. It is under its title, "the John Cummings Laboratory," by far the largest and the best in the world to-day. Its graduates are found in the most important mines and smelting and reduction works of the United States, showing the effect of their training at the Institute, in which theory and practice were so happily combined, and in which everything taught in the lecture-room is at once put to use in experiment and research.

In 1873 a further step in technical education led to the establishing of a laboratory of steam engineering. An engine of sixteen horse-power was set up, and the necessary apparatus for engine and boiler tests was provided. Out of this humble beginning has grown the largest and best equipped mechanical engineering laboratory to be found, in which not only is the work of instruction carried further than ever before, but original research, conducted jointly by the students and their instructors, is pushed to points often beyond the range of ordinary expert investigation within the profession. In the same year

the Lowell Free School of Industrial Design was established at the expense of the Lowell Institute, for the purpose of promoting the industries of the country, and especially the textile manufactures, by cultivating the American taste in respect to form and color.

In 1876 the system of shop work as a means both of general and professional training was introduced. Half an acre of shops, filled with the best tools, machines, and engines, with over two hundred students pursuing this branch of instruction, represent to-day the poor, mean shed, with its scanty appliances, which was all that the funds at the command of the Institute allowed to be erected in 1876.

In 1881 was established a laboratory of applied mechanics, devoted especially to the tests of building materials in wood, stone, and iron. The equipment of the laboratory has been increased from year to year, until it comprises a great variety of apparatus and machines, designed largely by the instructors in that department, for making almost every kind of test which the purposes of the engineer, the architect, the shipbuilder, or the mill-owner may require, — beam tests, column tests, belting tests, rope and wire tests, shafting tests, tests by tension, by transverse strain, by compression, by tensile strain, and continuous, intermittent, or instantaneous tests.

In 1884 the germ of a biological laboratory, which had existed in a corner of the shed used for the workshops of 1876, was developed with the aid of a large amount of physiological apparatus. The resources of the laboratory were turned, first, upon the preparation of its students for subsequent medical studies, and, secondly, upon bacteriological investigations, to which the marvellous discovery of Koch and Pasteur had pointed. It is not too much to say, that there is scarcely a place in this country where as much important bacteriological work has been done during the past three years as in this laboratory of the Institute.

In 1882 the increased demands upon the department of physics for the higher and more technical instruction of students, looking forward to electrical practice, led to the establishment of a distinct service devoted exclusively to that end, and, in connection with the new building of 1883, to the equipment of an electrical laboratory, with engine, dynamos, electric motors, and a great variety of electric testing apparatus. Notwithstanding this equipment, this course in electrical engineering, as it has been developed at the Institute, could not be sustained but for the machinery and ample appliances of the engineering laboratories. The training of the electrical engineer at the Institute of Technology differs from that usually followed, in that the electrical

engineer is here regarded as primarily a mechanical engineer, but a mechanical engineer who has specially studied the mechanical requirements of the electrical industries and enterprises, just as the chemical engineer under the course established two years ago is regarded in his relation to the chemical industries. And this introduces us to the last contribution made by the Institute of Technology to the philosophy of scientific and technical education, in the recognition of laboratory work in mechanics as an essential feature of a proper training in any branch of the great engineering profession. In the mechanical laboratories the students in each branch of engineering, civil, mechanical, mining, electrical, chemical, and sanitary, are called to perform the work of experiment, and to deal with the generation of power, and its application to the exigencies of their several contemplated professions.

We have thus roughly traced the history of the Institute of Technology. We have seen within how few years it has grown from a doubtful experiment into one of the most important schools of the country. We have seen how largely it has enjoyed the confidence and liberality of the public, and we feel that we may securely rely upon the same generous support hereafter. We have seen how its methods of instruction have been adapted to the changes and developments of practical science. We have seen that in this mobility, this power of adaptation, lay the grand idea of the whole scheme, and we are sure that, so long as it continues to be its guiding principle, the Institute of Technology will stand; a monument to the character, learning, and wisdom of its founder, worthy the community in which its establishment was possible and by which it has been maintained, an honor to the instructors who have devoted their energies to its service, and fortunate, as we trust it may long be, under the direction of so distinguished and able a President as General Francis A. Walker.

ADDRESS OF PRESIDENT WALKER, UPON PRESENTING DIPLOMAS OF GRADUATION.

My Friends, — It is now my pleasant privilege, on behalf of the Corporation and Faculty of the Massachusetts Institute of Technology, to present to you the diplomas of your honorable graduation and to greet you Bachelors of Science. It is rightly a subject of congratulation, on your part and on the part of all these friends, that you have passed so faithfully and patiently through one or another of the severe courses which lead up to the degree of the Institute. Doubtless at times it has gone much against the grain to do all that was required of you, and to do it all well. But you have striven, and you have conquered. Never hereafter can you be as those who have not been tried. I do not believe that any one of you to-day regrets the severe exertions and the great sacrifices that have been required. Those who do such things never regret the doing.

Behind you is a long course of laborious and honorable study and achievement; before you, a world which will never make upon you a severer demand than you have already successfully met. Are you not, then, glad that you have taken so brave a start in the cool of the day, and made so long a march in the morning of your lives, and now find yourselves so far on the way to personal and professional success, while sluggards are still droning and dozing away in camp the hours when the sun is low and the air is fresh and sweet? You are not to-day indulging in vain regrets as to hours which have been misspent, opportunities which have been neglected, and time that has been wasted in folly or vice. With the rightful pride of those who have fought a good fight, have kept the faith and finished their course with honor, you stand here and now, on the threshold of the great world, in the consciousness of duty hitherto well performed, of preparation for the labors of life carefully and thoroughly made, and of suitable and ample equipment for all the responsibilities of professional practice in the several lines for which you have been qualifying yourselves. I congratulate you. We say farewell without sorrow, since it was for this you came to us. But we bid you farewell in all affection and respect, with all honor and regard, with the most pleasant recollections of your straightforward and honorable conduct here, and with the strongest anticipations of your success and prosperity, both in professional and in private life.

THE NEW HYDRAULIC LABORATORY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

BY GEORGE F. SWAIN, HAYWARD PROFESSOR OF CIVIL ENGINEERING.

THE erection of the new engineering building of the Institute of Technology, to be occupied by the departments of Civil and Mechanical Engineering, offered an opportunity for a considerable extension in the Engineering Laboratories, and an attempt has been made to improve this opportunity by laying the foundation for a laboratory for hydraulic experiments, which should be so arranged as to permit of the carrying out of any experiments in hydraulics which it is practicable to perform within walls. Hydraulic experiments on a large scale must necessarily be performed out of doors, since the measurement of large quantities of water requires apparatus and appliances which cannot be accommodated within walls. Thus, the weir experiments of Mr. Francis, at Lowell, were made by taking the water from one of the canals, and using a lock as a measuring basin; those of Messrs. Fteley and Stearns, at South Framingham, were made by using a portion of the Sudbury River Aqueduct as a measuring basin; the orifice experiments of General Ellis, at Holyoke, were made in connection with the fall between two levels of the canal at that place; and the recent elaborate and careful experiments by Mr. Freeman on the flow of water through fire hose, the discharge of nozzles, and the height of jets, were made at Lawrence, where the hydrant system of one of the mills, as well as the city water supply, could be made use of.

But while experiments such as these are clearly excluded from among those which can be made in connection with a hydraulic laboratory in an institution of learning, there remain a large number which can properly be conducted within doors with the aid of suitable apparatus, and which, though they may be on a small scale as regards the quantities of water employed, nevertheless offer a large field for scientific investigation. The new laboratory of the Institute, as already stated, has been planned with a view to affording opportunity, as the work is extended, for carrying an any experiments which are thus practicable; that is to say, in the following directions: —

1. Experiments on the flow through orifices of small size, both free and submerged, and either sharp-edged, rounded, or fitted with

inside or outside mouth-pieces of various kinds, and under heads ranging as high as above seventy feet.

2. Experiments on the flow of water over weirs of small size, either free or submerged.

3. Experiments on the loss of head in small pipes of various kinds.

4. Experiments on the loss of head due to bends, curves, valves, diaphragms, or other obstructions causing sudden changes of velocity.

5. Experiments on the distribution of velocity in different parts of a liquid cross-section, either of a jet from an orifice, of a sheet discharged over a weir, or of a liquid flowing in a pipe.

6. Experiments on different water meters, including Mr. Herschel's Venturi meter, as well as the ordinary forms in the market.

7. The testing of small turbines and of various other small motors.

8. Experiments on the pressure of jets against plane or curved surfaces, and on the resistance of standing water to the motion of surfaces of different shapes through it.

9. Experiments on the siphonage of traps, and on other matters connected with plumbing arrangements of houses.

The development of a laboratory which shall admit of experiments in all these lines must necessarily be slow and expensive, and the laboratory in the Institute, being only a few months old, is not yet fully equipped to carry on any of these experiments excepting those on the flow of water through orifices. It is believed, however, that the foundation has been laid for the rapid development of research in the remaining directions which have been enumerated, and the object of the present paper is briefly to describe and illustrate the apparatus thus far provided or proposed.

In order to be able to work with large heads, and to be independent of the city water supply, as well as to provide for the varied experiments enumerated, it was first necessary to erect a tank and standpipe. The tank is shown in Figure 1. It is made of "Shell" steel $\frac{1}{4}$ inch in thickness, is 5 feet in diameter and about 28 feet high, resting on a concrete foundation and extending up through two floors. It consists of six courses of steel, with girth seams single riveted, and longitudinal seams double riveted, and with heads of $\frac{7}{16}$-inch steel dished as shown in the figure. It is provided with orifices as follows: —

In the lowest course, a man-hole 24 inches by 12 inches at M; at P, a flanged nozzle with elbow for connecting to 10-inch standpipe, as shown in Figure 15.

In the second course, a 10-inch orifice at G, a second at F, a third at D, and a fourth at C. The orifice at F may be used, if desired, for

connecting with a small turbine placed below the floor. That at G is for experiments on submerged orifices. Those at D and C are for experiments on free orifices, or for connecting lines of pipe with the tank. Enclosing the orifice at G, an angle-iron and two bent plates are attached to the side of the tank, as shown, to which a wooden tank extending horizontally and resting on the floor is to be attached. In this wooden tank will be placed a weir, and the water will flow through the submerged orifice at G, or through a submerged mouthpiece, either inside or outside, and either converging or diverging, and will then flow over the measuring weir. The orifice C is fitted for experiments on free orifices, as will subsequently be described. The orifice D is to be fitted with a piece to which pipes can be attached as desired, thus enabling the losses of head at diaphragms, valves, curves, etc. to be studied. On the same level with the orifices D and G connections are made for mercury gauges.

In the third course, a 1¾-inch orifice at G″ and another at C″, nearly above the large orifices G and C. These small orifices are for the shafts of the hand-wheels for raising the gates over the large orifices, as will presently be explained.

In the fifth course, orifices similar to those in the second course; and in the sixth course, orifices similar to those in the third course; thus rendering it possible to carry on experiments simultaneously upon two floors of the building. The top of the tank is provided with a flanged nozzle for connecting with the 10-inch standpipe, as shown in Figure 15.

The size of the tank is such that, with the orifices which it will be practicable to use, the velocity in the tank will be so small that it may be neglected, and the disturbance due to the inflowing water from the standpipe will also be small. Nevertheless, two gratings have been arranged, one at the top and one at the bottom. These gratings consist of plates of ⅛-inch iron perforated by ½-inch holes about an inch apart. They are made in three pieces, and rest upon angle-iron brackets riveted to the inside of the tank. The tank itself rests upon cast iron supports, as shown in Figure 1.

The general arrangement of the tank and standpipes is shown in Figures 15 to 18. Figure 15 shows the plan of the sub-basement, with the location of the tank, the rotary pump, and the steam pump. The tank *a* is connected, as shown, by the top connection *e* and the lower connection *f* to the 10-inch wrought iron standpipe *b*, which, as shown in Figure 17, extends to the top of the building, and is closed at the top. The connection *f* is tapped by the small pipe *g*, by means of

which the water may be drawn out of the system into the cistern *h*. The pumps take water from this cistern *h* and deliver it into pipe *k*, which, as shown in Figure 17, is arranged to carry it directly to the standpipe through the valve *s*, or to the 3-inch pipe *c* through the valve *t*. For use in the hydraulic experiments, the valve *s* is closed and the valve *t* opened, the water being thus delivered into the 3-inch pipe *c c*. From this pipe the flow into the 10-inch pipe is regulated by the valves *n*, which enable the head in the 10-inch pipe to be maintained at an almost perfectly constant level. Any excess of water overflows through the pipes *m* into the discharge pipe *d*. The pipe *c* therefore serves as a regulator of the head, and it has been found to fulfil its purpose admirably. Attached to the standpipe *b*, and running from floor to ceiling, in each story, is a glass gauge placed in front of a graduated scale reading to hundredths of a foot. These gauges are enclosed in wooden boxes, which may be opened on the front and on one side, and which are placed so as to receive light directly from adjacent windows. The water is taken by the pumps from the cistern *h*, passes through pipes *k* and *c* and through the valves *n* into the standpipe *b*, thence through the connection *e* or *f*, or both, into the tank, from which it is discharged through orifices, or in any other way desired, and the discharge measured. Measurements are made by weighing the quantity of water discharged in a given time, the water being returned to the cistern *h*, and thus used over and over again.

The same apparatus, by suitable arrangement of the valves, will be employed in making tests of the pumps.

The city water pipe is connected with the standpipe system at *x*.

The soil pipe *dd* is arranged with single and double Y's in a way which will allow the carrying out of all kinds of experiments on the siphonage of traps, as mentioned under head 9 on page 204. This pipe is arranged with an ordinary trap at the foot, as shown in Figure 16, and it discharges into the cistern *h*, as shown in Figure 15.

The details of the arrangement for measurements with simple free orifices are shown in Figures 2 to 14. In experiments of this description it is of course essential that the orifice shall be placed in a plane surface. It was therefore necessary to arrange the apparatus so that the curvature of the tank itself should not affect the flow. For this purpose, a composition casting *a* (Figs. 2 and 3) is drawn up to the tank by eight ⅝-inch bolts, as shown in Figure 3, which are screwed into the hub of the casting. The greater part of the casting is only ¼ inch in thickness, with eight strengthening ribs, as shown in Figure 2. In this casting is placed a piece, *c*, which is held in position by a ring-

nut, *dd*, which can be screwed or unscrewed by a spanner. When it is desired to use large or long orifices the piece *c* will contain the orifice, and by having various pieces *c*, with orifices of different shapes and sizes, numerous experiments may be carried out. The composition casting *a* is thickened on one side to ⅜ inch, as shown in Figures 2 and 3, to allow of the insertion of a sliding piece by means of which the horizontal dimension of a rectangular orifice may be varied, keeping the vertical dimension constant. When small orifices are to be used, it is not desirable to have them cut in as large a piece as the piece *c*. This piece *c*, therefore, as shown in Figure 3, is arranged to take a second piece, *o*, held in place by a second ring-nut, *d'*. Small orifices are made in pieces like the one *o*, as shown in Figure 3, and are of different sizes and shapes.

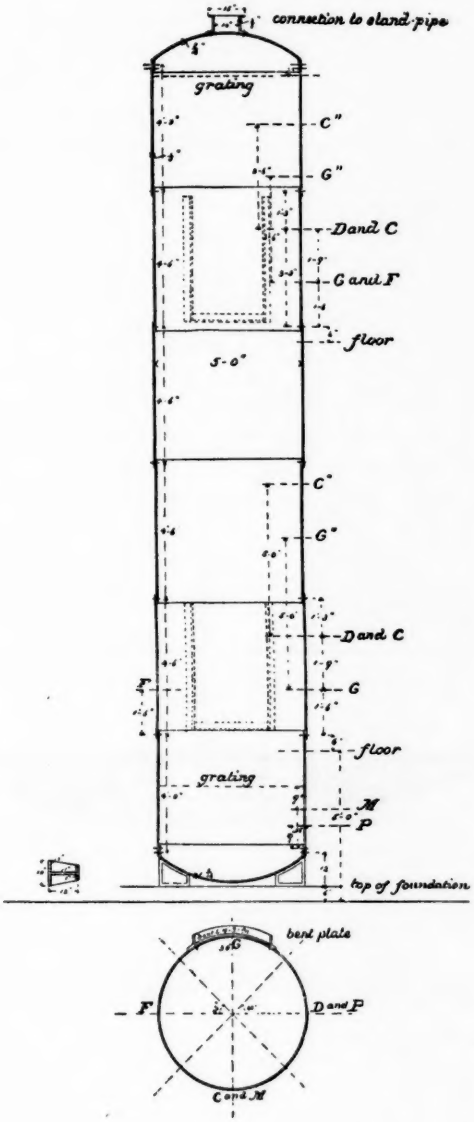
It is desirable that one orifice may be removed and another substituted in its place without completely emptying the tank. For this purpose, a gate is designed to slide on the back of the casting *a*, so that, when it is desired to remove one orifice, the gate may be lowered and the water thus shut off, and a new orifice substituted in place of the old one. The gate may then be raised and the experiments continued. This gate and the fittings connected with it are shown in Figures 4 to 14. Figure 4 shows a view of the gate from the inside, Figures 5 and 6 horizontal cross-sections, and Figure 7 a vertical cross-section. The gate is of cast iron, ribbed as shown, and is arranged to slide in guides bolted at the bottom to the casting *a*, and at the top to the tank. These guides are shown in Figures 8 to 11. In order that the gate may be raised without having to overcome the friction due to the pressure of the water over the entire surface of the gate, the rod *r*, by which the gate is raised, is attached to an angle-iron, *L* (Figs. 4 and 7). When the gate is to be raised from the position shown in Figure 7, the angle-iron *L* is first raised until it strikes against the rib above it. This raising of *L* opens the orifice *d*, thus allowing water to pass through the gate, and equalizing the pressure on the two sides, except over the small ring forming the bearing surface, the friction due to the pressure on which is, therefore, the only friction to be overcome. The discharge orifice may be meanwhile closed by a plug from the outside, if necessary. When the gate is lowered, its own weight carries it down until it reaches the stop *s*. The rod is then forced down, closing the orifice *d*. Figures 12 to 14 show the hand-wheel, shaft, and stuffing box, by means of which the gate is raised, and require little explanation. The rod shown in Figure 7 is in its upper part a rack running in the space *r* (Fig. 12).

Only one further point calls for explanation regarding the arrangement of the gate and stuffing box, namely, the modifications necessary for the case of inside mouth-pieces. When such mouth-pieces are used, the gate as shown would of course be inapplicable, and a new seat must be provided for it, so that it will pass clear of the inside mouth-piece. It is intended to accomplish this by bolting on to the composition casting *a* (Fig. 2) a circular channel-shaped rib, and adding new guides for the gate, thus making its seat at any desired distance back of the inside face of the casting. At the same time, in Figure 12 the pinion will be removed from the position shown, and placed outside of the bearing, where the collar is shown in the figure, and the collar placed on the inside. A new guide for the rack will then be bolted on, as shown by the dotted lines.

As the new engineering building has been occupied only since February, 1890, and the hydraulic apparatus is thus but a few months old, the only apparatus thus far in use is that for measuring the flow through simple, free orifices, and for making tests of pumps. It is hoped, however, that the remaining apparatus will be provided in the near future. The tank and the standpipe system already procured furnish the foundation, and upon them the other apparatus may readily be built up. Experiments upon meters and upon motors may also be carried out without difficulty; and, in fact, the possible lines of research are so varied that it is hoped that the establishment of this laboratory may lead to many useful results, and that it may contribute in some measure to the advancement of hydraulic science.

Steel Tank

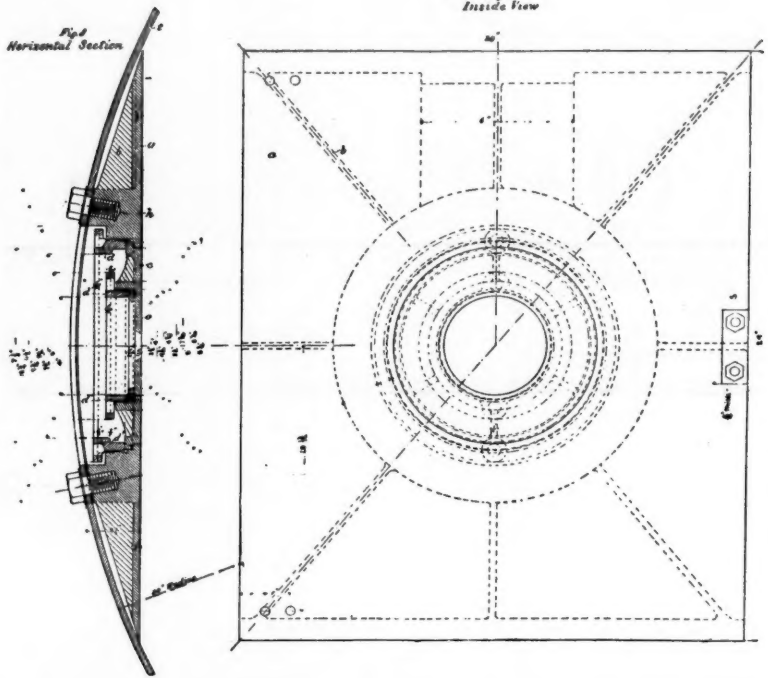
Fig. 1.

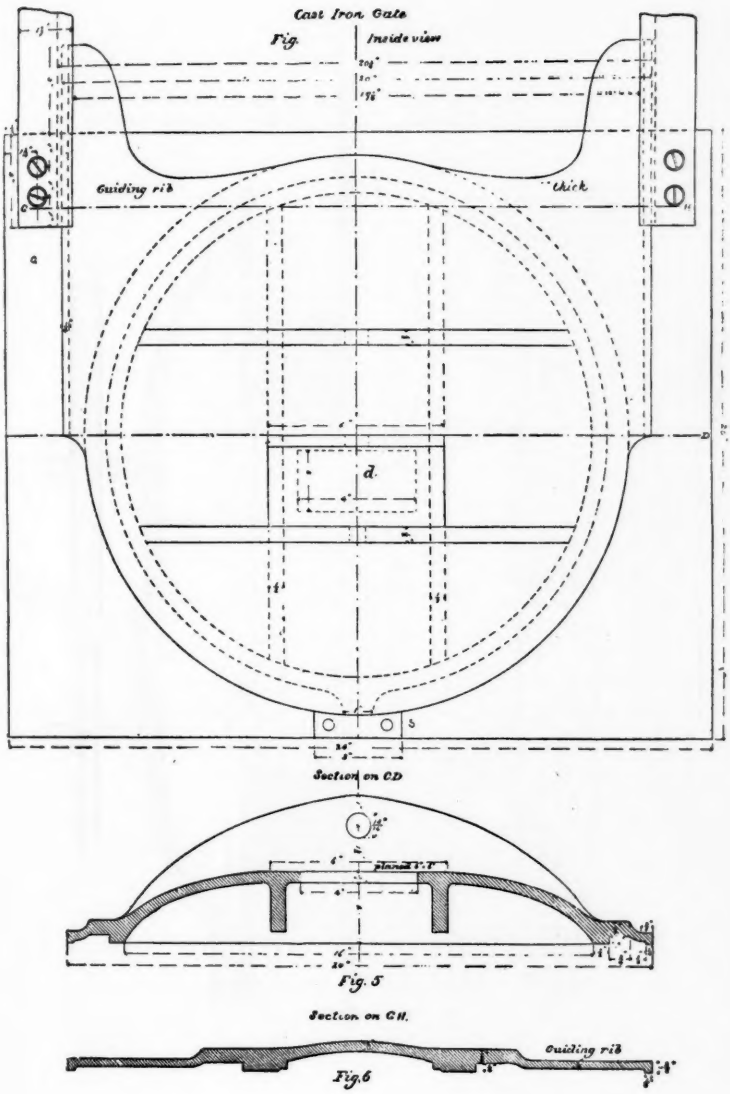


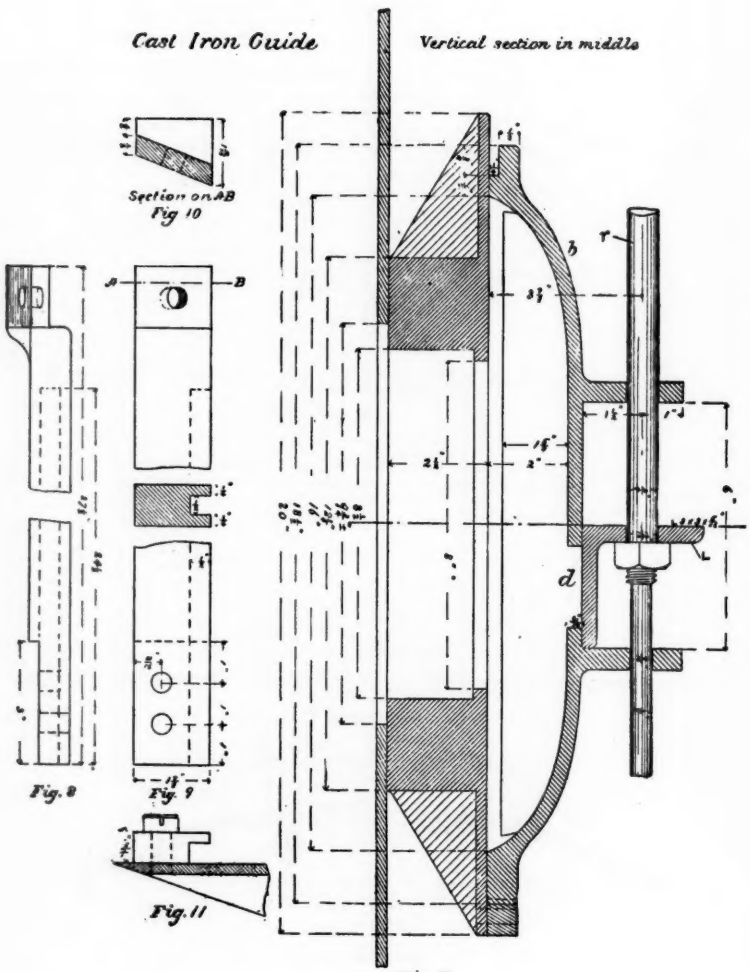
Details of Drum Casting

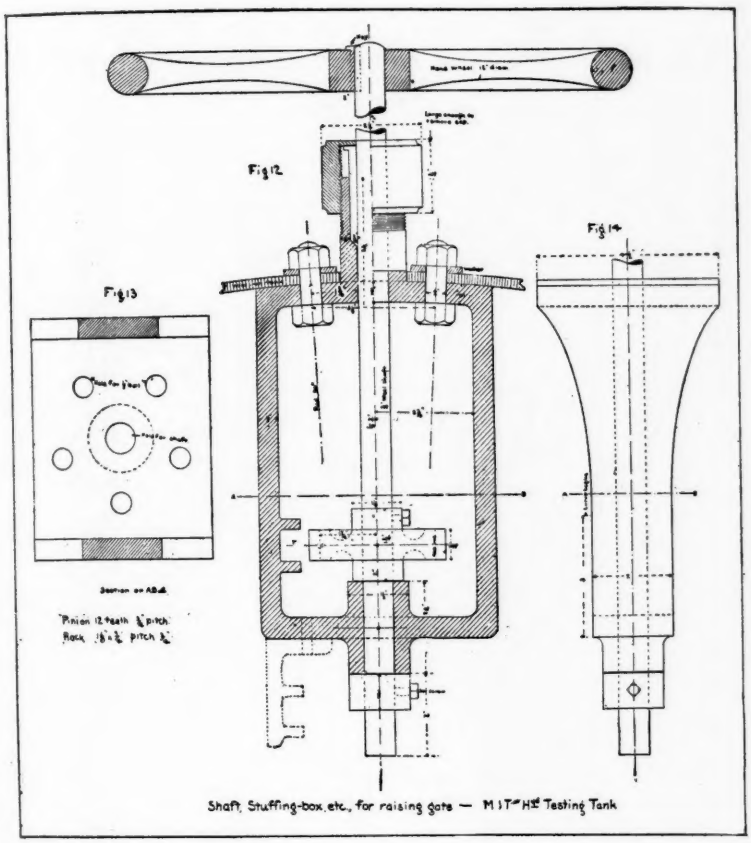
Fig 2
Inside View

Fig 1
Horizontal Section




Cast Iron Gate
Fig.
Inside view
Guiding rib
Thick
d.
Section on CD
Fig. 5
Section on GH.
Guiding rib
Fig.6


Cast Iron Guide
Vertical section in middle
Section on AB
Fig 10
Fig. 8
Fig. 9
Fig. 11
Fig. 7
A
B
b
d



Shaft, Stuffing-box, etc., for raising gate — M.I.T.ᵐ H.ᵒ Testing Tank

Fig 15

Plan of Sub-basement

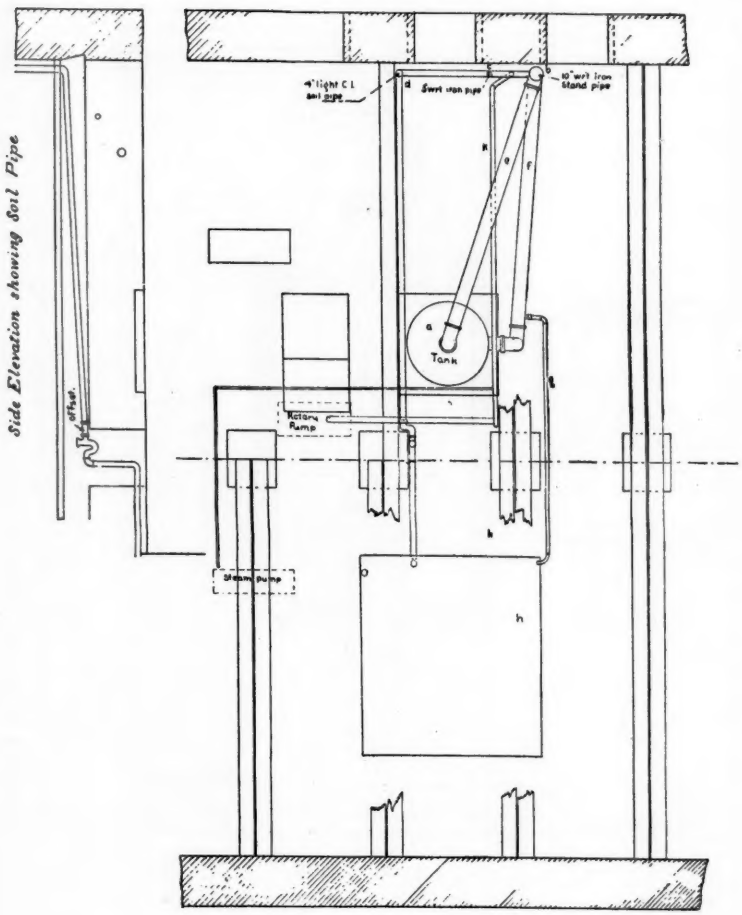


Fig 16

Side Elevation showing Soil Pipe

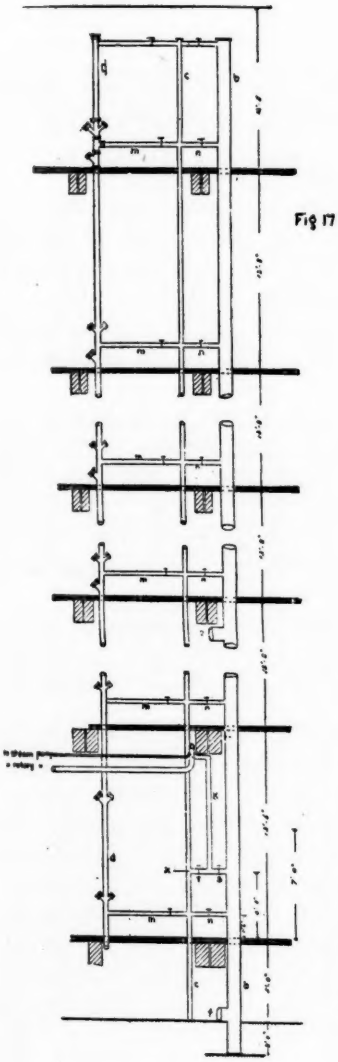


Fig 17

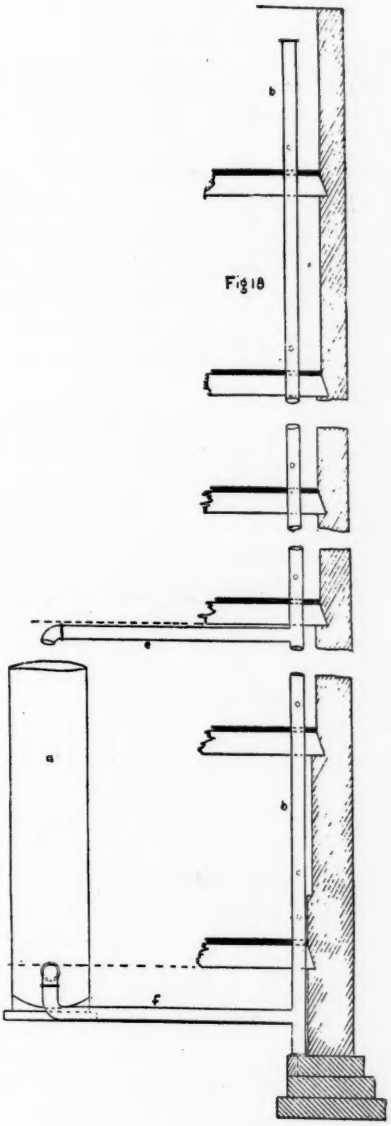


Fig 18

ON THE EXTENT OF THE EXCURSION OF THE ELECTRODES OF A MICROPHONE TRANSMITTER.[1]

BY CHARLES R. CROSS, THAYER PROFESSOR OF PHYSICS.

THE character and extent of the motions of the electrodes of a microphone transmitter, when actuated by sound-waves of different degrees of intensity, is a subject in telephony of by no means slight importance, but to which very little study has been given. The present paper describes the results of some observations relating to this subject, which have been made at various times during the past two years.

Several years ago an attempt was made by Mr. W. W. Jacques and the writer to gain some knowledge as to the amplitude of the vibrations of the hammer electrode of a microphone, by observing it with a microscope while in operation, and noting the extent of the blurred portion of the image. The results, though giving all that could be expected from so crude a method, were not very satisfactory so far as definite measurement was concerned.

It afterwards occurred to the writer that the matter might be studied more completely by the use of the stroboscopic method, and an arrangement of apparatus was adopted by which the motions of the electrodes could readily be observed.

This was done in the following manner. The microphone to be studied was placed in the field of a microscope, whose line of collimation was horizontal. Behind the microphone, at a suitable distance, was placed a Helmholtz mercury interrupter, with a tuning-fork making 128 vibrations per second. The extra current due to the electromagnets of the interrupter was quite large, so that a brilliant spark was obtained at each rupture of the circuit, as the platinum style of the interrupter left the mercury. The interrupter being properly placed, and the light of the spark concentrated by a lens, quite a bright field was obtained, against which the electrodes were seen projected, as silhouettes. The light, though intermittent, of course seemed continuous, since the sparks were so numerous. When good definition was obtained, the microphone was set in operation, usually by means of an organ-pipe placed at a convenient and variable distance, and in

[1] Read at a meeting of the American Academy of Arts and Sciences, April 9, 1890.

some experiments by the voice. The pipe was blown by a constant blast, and great uniformity of intensity in the sound was secured. An open C_3 organ-pipe making approximately 256 double vibrations per second was commonly used, its pitch being variable to a moderate extent by shading the mouth or the opening at the top.

So long as the pipe was an exact octave in pitch above the interrupting fork, the electrodes of the microphone as seen with the microscope appeared to be at rest; but if the interval was slightly disturbed, the stroboscopic effect was observed, and the electrodes seemed to move slowly through their complete course. The rate of this apparent vibration was of course dependent upon the deviation of the pipe from exactness in its interval with the fork, and could be varied at will within quite wide limits.

The extent of the motion of the electrodes could be determined by observing the grains of dust which adhered to them, or some definitely marked roughness on their surface. Measurements were made by means of a spider-line micrometer, the wires of which were placed at a convenient distance apart, and the amplitude of the motions of the selected points of reference on the microphone was determined by estimating the relation of their apparent motion to the distance separating the wires of the micrometer. This last distance was frequently varied to diminish the liability to error from a possible bias of the observer towards an agreement with earlier results.

In the experiments described in the present paper, the electrodes were generally so adjusted that the motion of the anvil electrode was too small to be observed. Under these circumstances the observed motion of the hammer electrode, as measured by the micrometer, was the motion of this relatively to the anvil electrode, which is of course the quantity to be determined, rather than the actual excursion of the hammer electrode.

The microphone was placed in circuit with a battery and the primary of an induction coil, whose secondary contained a receiving telephone. With this arrangement the effect on the ear of the electrical variations due to the various values of the excursions of the electrodes could readily be observed. In many cases a second observer was stationed at the receiving telephone, which was then placed in a separate room.

Magnifying powers were used of from 50 to 1,000 diameters. With the higher powers the use of an objective of short focal length was difficult on account of the small working distance, so that, although even as short a focus as $\frac{1}{10}$ in. was sometimes employed, it was found

much preferable to obtain the needed magnification by the use of short focus eye-pieces.

The brilliancy of the electric spark was amply sufficient for illumination of the field, even with the highest magnification employed; a fact which calls attention vividly to the enormous "instantaneous intensity" (so to call it) of that light. Considering the excessively brief duration of the spark and the very small quantity of matter illuminated, it seems unquestionable that the intrinsic brilliancy is far greater than that of the electric arc, a view fully supported by the results of spectroscopic study.

Various forms of microphone were observed, but the general features characterizing the actions studied were common to them all. As the intensity of the sound acting on the microphone was increased by approaching the organ-pipe to the diaphragm, the motion of the hammer electrode, at first absolutely invisible, was seen gradually to increase, until, when the intensity was very great, the motion was excessive, the anvil electrode being violently pushed aside, and the hammer leaving it on its return motion, so that the circuit was broken at every vibration. At the same time bright sparks were seen between the electrodes. To the ear the simultaneous acoustic changes in the sound transmitted were very striking. The sound of the pipe was distinctly audible, and its quality clear, with motions of the hammer electrode far too slight to be observable. As the sound actuating the telephone became louder, and the excursion of the electrode became visible, the quality continued good, the sound transmitted growing louder; and then, as the excursion increased further, the quality gradually changed, shrill false notes made their appearance, and the sound began to grow harsher, until finally, when breaks appeared in the current, the sound was excessively harsh, and entirely devoid of musical quality. Long before this, however, the characteristic quality of the organ-pipe disappeared.

The following tables will illustrate the results obtained. In making many of the measurements I worked in company with Mr. W. W. Jacques, whose observations were always in substantial accord with my own. A large number of observations have also been made, under my direction, by Messrs. A. W. Jones and F. L. Dame, students in the Laboratory, whose work has been performed with conscientiousness and accuracy.

The microphone used in most of the experiments was one in which the anvil electrode was a "pendulum electrode," suspended by a vertical rod, hinged at the top, and so weighted as to give to it a proper

mass. The desired normal pressure could be obtained by sliding the point of suspension laterally so as slightly to incline the supporting rod, and further, by adding a weight so as to exert a proper leverage, if this was desired. The hammer electrode was pointed and carried by the diaphragm, which was of mica. The sounding pipe was gradually removed from or approached toward the microphone. Care was in all cases taken to keep the wind pressure constant. A single Leclanché cell was ordinarily used, though in a few cases a Grénet cell was employed.

In the various tables, the excursions of the electrodes are in all cases given in fractions of an inch. In designating the material of the electrodes, that of the anvil is stated first.

Tables I. to III. show the results obtained when both electrodes were of carbon; Tables IV. and V., when the anvil electrode was of carbon, the hammer of platinum. Tables VI. to VIII. contain results of observations made with a modified form of transmitter, in which the anvil electrode was also somewhat heavier than in the earlier experiments.

TABLE I.

ELECTRODES, CARBON, CARBON. — *Magnification*, 50 *diameters.*

Excursion.	Character of Sound.
1000×10^{-6} to 700×10^{-6}	Constant breaking and sparks. Electrodes visibly separating.
600×10^{-6}	Constant sparking. Electrodes occasionally seen to separate.
200×10^{-6}	Occasional breaks and sparks.
200×10^{-6}	Scratchy sound, no sparks.
No visible motion.	Sound clear and smooth.

TABLE II.

ELECTRODES, CARBON, CARBON. — *Magnification*, 50 *diameters.*

Excursion.	Character of Sound.
1000×10^{-6} to 600×10^{-6}	Constant sparks; electrodes separating.
300×10^{-6} to 200×10^{-6}	Harsh; occasional breaks and sparks.
150×10^{-6}	Scratchy.
No visible motion.	Clear and smooth.

Whenever the excursion of the hammer was greater than 100×10^{-6} the sound was very scratchy and harsh.

TABLE III.

ELECTRODES, CARBON, CARBON. — *Magnification*, 160 *diameters.*

Excursion.	Character of Sound.
350×10^{-6} to 300×10^{-6}	Loud, noisy, harsh.
250×10^{-6} to 200×10^{-6}	Very scratchy.
120×10^{-6} to 80×10^{-6}	Scratchy, but less than before.
150×10^{-6} to 100×10^{-6}	Scratchy, but with high overtones.

At the lowest amplitude given in Table III. the quality of the sound of the pipe was first heard, but a still less amplitude was necessary for its satisfactory reproduction.

TABLE IV.

ELECTRODES, CARBON, PLATINUM. — *Magnification*, 160 *diameters.*

Excursion.	Character of Sound.
250×10^{-6}	Constant sparks and breaks.
120×10^{-6}	Scratchy; occasional sparks and breaks.
70×10^{-6}	Raspy.
50×10^{-6}	Quality distinct, but high squealing overtones present.
20×10^{-6}	Quality better; fewer high overtones.
Less than 20×10^{-6}	Quality better; some high overtones still audible.

The pipe had to be carried twice as far away from the transmitter as in last measurement, to a distance of eighteen inches, before the quality became really excellent.

TABLE V.

ELECTRODES, CARBON, PLATINUM. — *Magnification*, 150 *diameters.*

Excursion.	Character of Sound.
120×10^{-6}	Very scratchy; occasional sparks.
60×10^{-6}	Squealing, high overtones.
40×10^{-6}	Fair quality; high overtones prominent.
$< 20 \times 10^{-6}$	Good quality; a little rough.
400×10^{-6}	Constant breaking.
60×10^{-6}	Very raspy.
40×10^{-6}	High overtones strong.
20×10^{-6}	Quality good.

TABLE VI.

ELECTRODES, CARBON, PLATINUM. — *Magnification*, 700 *diameters.*

Excursion.	Character of Sound.
200×10^{-6}	Rough, but pitch discernible.
80×10^{-6}	Rough, pitch distinct.
30×10^{-6}	Smooth, with high overtones.
30×10^{-6}	" " "
20×10^{-6}	Quality good; some high overtones.
10×10^{-6}	Good quality.
25×10^{-6}	Smooth, with high overtones.
30×10^{-6} to 40×10^{-6}	High overtones prominent.
80×10^{-6}	Harsh and rough.

TABLE VII.

ELECTRODES, CARBON, PLATINUM. — *Magnification*, 940 *diameters.*

Excursion.	Character of Sound.
1000×10^{-6} to 800×10^{-6}	Scratchy, with breaks.
100×10^{-6}	Rough, with high overtones.
80×10^{-6}	Wheezy, with high overtones.
40×10^{-6}	Smooth, but with high overtones.
30×10^{-6}	" " "
60×10^{-6}	Rough, with high overtones.
50×10^{-6}	Harsh, with high overtones.
40×10^{-6}	Smoother.
30×10^{-6}	Smoother, with high overtones.
20×10^{-6} to 30×10^{-6}	Good quality, high overtones present.
20×10^{-6}	Good quality.

TABLE VIII.

ELECTRODES, CARBON, PLATINUM. — *Magnification*, 940 *diameters.*

Excursion.	Character of Sound.
1000×10^{-6}	Harsh and screamy.
2000×10^{-6}	" "
1000×10^{-6}	High overtones heard; no distinct pitch transmitted.
400×10^{-6}	High strident overtones present.
100×10^{-6}	High overtones still present.
60×10^{-6}	Sound wheezy.
30×10^{-6}	Sound smooth.
20×10^{-6} to 10×10^{-6}	Quality good.

The differences in the effects obtained with a microphone in which both electrodes are of carbon, as compared with one in which one of the electrodes is of platinum, are well known to every one who has considered the subject. While with the latter it is more easy to produce an actual break of contact between the electrodes than with the former when the sound is increased, on the other hand the quality is much more satisfactorily reproduced, and does not so rapidly disappear on increasing the loudness. These differences were clearly noticed in the observations. Thus for slight excursions of the hammer electrode the quality of the sound with two carbon electrodes was found to be less satisfactory than when the hammer was of platinum, although in the latter case the point of actual breaking of circuit and sparking was usually reached with a less excursion than in the former one. Evidence of these differences appears in the tables just given, and also in those which follow.

It must be observed, that, while the figures given in the tables show what is the maximum amplitude of vibration of the electrodes con-

sistent with the transmission of quality, they entirely fail to indicate the excessive minuteness of the least excursions which are capable of this result. How minute these sometimes are may be inferred from the following observation.

With a microphone having a somewhat heavy anvil electrode, the organ-pipe was gradually moved away from the diaphragm, and the diminishing range of motion of the electrodes noted in the usual manner. When the pipe was at a distance of three inches the motion of the electrodes was too slight to be visible, although this could have been seen readily with the low magnifying power employed if it had been as great as $\frac{1}{20000}$ in. The pipe, still blown with the same loudness, was then carried farther and farther away. At a distance of thirty-six feet, which was the most distant point from the microphone in the room, the sound of the pipe was still distinctly though faintly audible at the receiver placed in circuit with the microphone, and in a distant apartment.

The results shown in the preceding tables give an idea of the phenomena observable with a microphone of the structure employed. Inasmuch as the primary object of the measurements was to obtain some idea of the actual value of the excursion of the electrode, the mass and normal pressure of the electrodes were not particularly considered, except that they were so adjusted as to give good transmission with moderate loudness of the sound actuating the microphone. But it would of course be expected that the numerical value of the relative excursion of the electrodes corresponding to any given character of sound would vary with the mass of the anvil electrode and with the normal pressure between the electrodes. Two separate sets of observations were made to observe the effects of such variations, by Messrs. Jones and Dame. The latter series was somewhat more complete than the former, besides being carried on with better instrumental appliances, and the results hereafter given are taken chiefly from it.

In all experiments of the nature of those under consideration, it is very difficult to get any fixed standard of quality to which to refer such results as the present. Different observers differ to a certain extent in their estimate of the excellence of the quality reproduced. But the point at which the distinctive quality of the transmitted sound disappears is quite well marked, and a very slightly increased vibration of the hammer electrode causes great harshness to result. For this reason, the name "critical point," originally suggested by Mr. Jones, has been given to this limit, and the excursion corresponding to it has been particularly noted, in tests of the varying effects of mass and pressure.

The transmitter used had its anvil electrode suspended like a pendulum, as before. In order to vary the mass without varying the normal pressure, a horizontal wire was suspended beneath the anvil electrode and rigidly attached to it. The middle point of the wire was vertically beneath the point of suspension of the electrode. The masses added consisted of small copper washers weighing 1.1 grams each. By adding two of these whenever the mass was to be increased, and placing one on each side of the middle point of the horizontal wire, the mass of the electrode was increased, while the normal pressure remained substantially constant. In the experiments whose results are contained in Tables IX. to XIII. the normal pressure was exceedingly small, the electrodes always being kept in very light contact. This condition of things was easily secured by a slight adjustment of the position of the washers. A magnification of 280 diameters was usually employed.

The following results were obtained by the mode of procedure just described.

TABLE IX.

ELECTRODES, CARBON, PLATINUM.

Mass in Grams.	Excursion of Hammer at Critical Point.
4.0	12×10^{-6}
8.1	25×10^{-6}
10.3	37×10^{-6}
12.5	50×10^{-6}
14.7	50×10^{-6}
17.0	50×10^{-6}
19.2	50×10^{-6}
21.4	50×10^{-6}

TABLE X.

ELECTRODES, CARBON, PLATINUM.

Mass in Grams.	Excursion of Hammer at Critical Point.
4.8	12×10^{-6}
5.9	25×10^{-6}
8.1	37×10^{-6}
10.3	37×10^{-6}
12.5	50×10^{-6}
14.7	50×10^{-6}
17.0	50×10^{-6}
19.2	50×10^{-6}

TABLE X. — *Continued.*

Mass in Grams.	Excursion of Hammer at Critical Point.
21.4	50×10^{-6}
25.8	50×10^{-6}
4.5	12×10^{-6}
8.7	25×10^{-6}
10.9	37×10^{-6}
13.1	50×10^{-6}
17.5	50×10^{-6}
21.9	50×10^{-6}

TABLE XI.

ELECTRODES, CARBON, CARBON.

Mass in Grams.	Excursion of Hammer at Critical Point.
8.5	18×10^{-6}
10.7	18×10^{-6}
12.9	25×10^{-6}
15.1	25×10^{-6}
17.3	25×10^{-6}
19.5	37×10^{-6}
21.7	37×10^{-6}
23.9	37×10^{-6}
28.3	37×10^{-6}

TABLE XII.

ELECTRODES, CARBON, CARBON.

Mass in Grams.	Excursion of Hammer at Critical Point.
5.7	12×10^{-6}
8.7	17×10^{-6}
10.9	25×10^{-6}
13.1	37×10^{-6}
15.3	37×10^{-6}
17.5	37×10^{-6}
19.7	37×10^{-6}
5.7	12×10^{-6}
9 1	18×10^{-6}
11 3	37×10^{-6}
15 5	37×10^{-6}
15 7	37×10^{-6}
17 9	37×10^{-6}
20.1	37×10^{-6}

TABLE XIII.

ELECTRODES, PLATINUM, PLATINUM.

Mass in Grams.	Excursion of Hammer at Critical Point.
7.65	12×10^{-6}
9.85	25×10^{-6}
12.05	31×10^{-6}
14.25	37×10^{-6}
16.45	37×10^{-6}
18.65	37×10^{-6}
20.85	37×10^{-6}
7.65	12×10^{-6}
9.85	25×10^{-6}
12 05	37×10^{-6}
14.25	37×10^{-6}
18.65	37×10^{-6}
20.85	37×10^{-6}

An inspection of Tables IX. to XIII. shows that the value of the excursion of the hammer electrode corresponding to the "critical point," and presumably, therefore, the excursion corresponding to any given degree of excellence in the reproduction of quality, at first rises very rapidly as the mass of the anvil electrode is increased, but soon reaches a maximum value, which is not altered by further increase of mass. The rise appears to be less rapid when both electrodes are of carbon, than when one or both of them are of platinum, as may be seen by a comparison of the various tables, or, better still, by plotting the results so as to exhibit them graphically by curves. Also, when both electrodes are of carbon or both of platinum, the maximum and permanent excursion at the critical point is considerably less than when the hammer electrode is of platinum and the anvil of carbon, — a fact which goes to explain the well known excellence of a microphone employing these last materials. Further experiment is desirable, however, before fully accepting this explanation. Furthermore, variations in the surface and shape of the electrodes are likely to modify these values to a certain extent. Thus the carbon electrodes used by Mr. Jones gave the results shown in Tables XIV. and XV. The arrangement of the electrodes was as already described, except that the anvil was slightly inclined, and in the second series a weight of bent wire was added to increase the normal pressure by a small amount.

TABLE XIV.

ELECTRODES, CARBON, CARBON.

Mass in Grams.	Excursion of Hammer at Critical Point.
6.5	36×10^{-6}
8.9	50×10^{-6}
11.3	60×10^{-6}
13.7	60×10^{-6}
16.1	60×10^{-6}
18.5	60×10^{-6}
20.9	60×10^{-6}
23.3	60×10^{-6}
25.7	60×10^{-6}

TABLE XV.

ELECTRODES, CARBON, CARBON.

Mass in Grams.	Excursion of Hammer at Critical Point.
2.9	20×10^{-6}
5.3	30×10^{-6}
7.7	40×10^{-6}
10.1	55×10^{-6}
12.5	60×10^{-6}
14.9	60×10^{-6}
17.3	60×10^{-6}

In connection with the various preceding tables the following results obtained by Mr. Jones will be of interest.

TABLE XVI.

ELECTRODES, CARBON, PLATINUM.

Series.	Magnification.	Excursion for Good Quality	Excursion at Critical Point.	Excursion for Breaking.
1	400	16×10^{-6}	60×10^{-6}	80×10^{-6}
2	400	20×10^{-6}	$30\text{-}40 \times 10^{-6}$	60×10^{-6}
3	400	30×10^{-6}	50×10^{-6}	80×10^{-6}
4	350	30×10^{-6}	60×10^{-6}	80×10^{-6}
5	700	40×10^{-6}	60×10^{-6}	80×10^{-6}
6	1000	30×10^{-6}	70×10^{-6}	80×10^{-6}

In Series 2 the normal pressure was slightly less than in the others. The excessively high value of 40×10^{-6} at which in Series 5 good quality still persisted, is the highest that has been observed. The hammer electrode had been brought to a sharp point just previously.

I have observed, among the four persons who have employed the method under consideration, that each one has apparently his own standard of what constitutes good quality, and usually adheres quite closely to this in different experiments. The observer last cited generally gave somewhat larger values to the excursion for a given degree of excellence of transmission than I noted in my own observations, apparently from this cause.

A further series of measurements was made in order to ascertain what effect was produced by a variation in the normal pressure between the electrodes.

In order to do this, a wire was caused to project backward from the anvil electrode, and small weights were hung upon the end of it. The pendulum electrode with this projecting wire constituted a bent lever

whose arms were easily measured, thus enabling the normal pressure due to a given weight to be calculated. It was thus obtained very easily, although the method is subject to the objection that there is a certain variation of the mass of the anvil electrode simultaneously with the variation in pressure. The use of a delicate spring instead of the weight would be preferable, but I have not yet found time to carry through observations by this method. The results reached are shown in Tables XVII. to XIX.

TABLE XVII.

ELECTRODES, PLATINUM, PLATINUM.

Normal Pressure in Grams.	Excursion of Hammer at Critical Point.
0.34	8×10^{-6}
0.77	14×10^{-6}
1.20	25×10^{-6}
1.63	37×10^{-6}
2.06	50×10^{-6}
2.50	61×10^{-6}
0.34	10×10^{-6}
0.77	12×10^{-6}
1.20	25×10^{-6}
1.63	37×10^{-6}
2.06	50×10^{-6}
2.50	61×10^{-6}
2.93	61×10^{-6}

TABLE XVIII.

ELECTRODES, CARBON, CARBON.

Normal Pressure in Grams.	Excursion of Hammer at Critical Point.
0.297	8×10^{-6}
0.632	12×10^{-6}
0.990	12×10^{-6}
1.288	12×10^{-6}
1.650	25×10^{-6}
2.150	25×10^{-6}
0.272	8×10^{-6}
0.616	25×10^{-6}
0.960	37×10^{-6}
1.304	37×10^{-6}
1.648	37×10^{-6}
1.990	37×10^{-6}

TABLE XIX.

ELECTRODES, CARBON, PLATINUM.

Normal Pressure in Grams.	Excursion of Hammer at Critical Point.
0.184	8×10^{-6}
0.288	12×10^{-6}
0.432	12×10^{-6}
0.632	12×10^{-6}
0.990	12×10^{-6}
1.288	12×10^{-6}
1.654	Anvil vibrating.
0.104	$>8 \times 10^{-6}$
0.132	$>8 \times 10^{-6}$
0.153	8×10^{-6}
0.180	8×10^{-6}
0.395	12×10^{-6}
0.620	12×10^{-6}
0.644	12×10^{-6}
0.149	8×10^{-6}

It appears from these results, that the value of the excursion corresponding to the critical point rises with increase of normal pressure, soon attaining a maximum and constant value. The pressure at which this maximum value was reached was greatest when both electrodes

were of platinum, and least when the hammer electrode was of platinum and the anvil of carbon. When both electrodes were of carbon, the value lay between these two extremes. The unexpected result was also reached that the value of the maximum excursion was much greater when both electrodes were of platinum than when both were of carbon. It was least when the hammer was of platinum and the anvil of carbon.

A series of observations was also made upon the microphone of the Blake transmitter. These presented considerable difficulty on account of the construction of the parts of that instrument, and only a low magnification could be used. Three sets of measurements were taken, the first with a very light normal pressure, the second with the ordinary pressure, and the third with a very heavy pressure. With this microphone in its proper condition, both electrodes moved. It was therefore necessary to subtract the excursion of the anvil electrode from that of the hammer, in order to obtain their relative motion. The results reached are given in Table XX. The total excursion of the hammer electrode, and its motion relative to the anvil, are given as nearly as they could be measured.

TABLE XX.

BLAKE TRANSMITTER. — ELECTRODES, CARBON, PLATINUM.

Total Excursion.	Relative Excursion.	Character of Sound.
	a. *Light Normal Pressure.*	
	$<25 \times 10^{-6}$	Good quality, very faint.
50×10^{-6}	25×10^{-6}	" " clear.
100×10^{-6}	50×10^{-6}	Overtones strong.
	b. *Medium Normal Pressure.*	
	$<25 \times 10^{-6}$	Good quality, very faint.
75×10^{-6}	25×10^{-6}	" " clear.
100×10^{-6}	50×10^{-6}	Overtones strong.
	c. *Heavy Normal Pressure.*	
	$<25 \times 10^{-6}$	Good quality, very faint.
100×10^{-6}	25×10^{-6}	" " clear.
150×10^{-6}	50×10^{-6}	Overtones strong.

These results, although of only approximate exactness, are interesting, as they show one cause of the excellence of the Blake transmitter in practice, in that the mode of support of the electrodes allows of very considerable variations in the absolute motions of both of them without material change in their relative motions.

ROGERS LABORATORY OF PHYSICS,
March, 1890.

THE KAOLIN IN BLANDFORD, MASS.

BY WILLIAM O. CROSBY, ASSISTANT PROFESSOR OF MINERALOGY AND LITHOLOGY.

THE existence of a considerable body of white kaolin of a high degree of purity in the town of Blandford, in Hampden County, Massachusetts, has been known for fifteen years. But it is only within the last year that sufficient excavations have been made clearly to reveal the geological relations and probable origin of the kaolin; and even now the full extent of the deposit is very imperfectly known. I am indebted to Mr. George L. Twichell for an opportunity, on two different occasions, to make as thorough a study of the kaolin *in situ* as the excavations would permit. My first examination was made in May, 1889; but since the obvious commercial importance of the deposit gave promise of considerable development during the year, the preparation of this account was purposely delayed until I should be able to make a second visit to Blandford, which was not until April of the present year.

The kaolin has been derived from large veins of a coarse pegmatite, or endogenous granite, containing little mica and consisting chiefly of feldspar, and it is clearly the product of decomposition *in situ* in pre-glacial times, — a genuine remnant of an ancient sedentary soil, which, through some fortunate circumstance, has escaped the powerful erosive action of the great ice-sheet. On account of the relations of the kaolin to glaciation, its topography has a special interest, and will be described in greater detail than would otherwise seem necessary.

Blandford lies on the south side of the Westfield River, well within the border of the crystalline formations, and is a typical example of the hill towns of western Massachusetts. The view, however, from the summit of any of the broadly rounded ridges traversing the town embraces a surprisingly small number of elevations projecting decidedly above the general level. But it is very clear that this region of crystalline and highly disturbed strata, although exhibiting the structure of mountains, is topographically simply a peneplain, having an elevation of fifteen hundred to two thousand feet above the sea, sloping gently eastward toward the Triassic valley, and deeply grooved by the Westfield River and its tributaries. In other words, this is a district which, having been worn down by the agents of erosion nearly to its base level, has been strongly elevated, establishing a new and lower base

level, so long ago that a strongly marked and complex drainage system has since been developed, and yet not so long ago but that considerable remnants of the old peneplain or base-level plain are still preserved in the higher parts of the interstream surfaces.

The village of Blandford Centre is situated on the top, but near the south end, of a prominent ridge which extends in a north-northwest direction for several miles to Green Mountain and the Westfield River, and gives off various spurs or subordinate ridges. The principal part of the village really lies in the faintly marked saddle connecting the main ridge with the north end of a short parallel ridge. The main street of the village runs in a southeasterly direction across the northern end of this subordinate ridge, and makes a slight descent on the east side of it to a nearly level tract or meadow some two hundred feet in width, beyond which the ground rises slightly before descending on the northeast to the valley of Great Brook. The meadow, which appears essentially as a shoulder of the ridge, is merged on the north with the general rounded outline of the ridge; but where it is crossed by the highway it is quite level, and then slopes gently to the southeast, parallel with the road on the northeast, and, in a general way, with the ridge on the southwest, the ridge rising about eighty feet above the meadow. The trend of this ridge is about north-northwest and south-southeast, or almost exactly parallel with the glacial striæ upon its ledges of schist and granite; and it is thus apparent that the elevated meadow, which is the exact location of the kaolin, is not, with reference to glacial movement, in the lee of the ridge, or of any ground rising above its own level, but it was, so far as can be seen, exposed to the full sweep of the ice.

The ridge above the meadow, like the main ridge of which it is a spur, and like all the surrounding country so far as examined, is mainly composed of a distinctly crystalline and typical mica schist. The beds are occasionally garnetiferous, and are quite frequently interstratified with a fine-grained and well laminated hornblende schist. The general strike of the beds is about north and south, and a vertical or very high westerly dip prevails; but both of these elements of the bedding exhibit great irregularities, the strike especially varying widely and rapidly from the normal direction. These local flexures or contortions of the strata are evidently related in many cases to the great veins of coarse granite or pegmatite which traverse the schists. These consist chiefly of coarsely crystalline or cleavable potash feldspar, with usually some muscovite and quartz. The muscovite crystals rarely exceed two or three inches in breadth, and

when larger are likely to be somewhat affected by corrugation and wrinkling. On this account, chiefly, the exploitation some years ago of one of these veins, in which the crystals are larger than usual, for commercial mica and feldspar, proved unprofitable. The quartz is sometimes abundant, especially in the smaller veins, and frequently forms a beautiful graphic granite with the feldspar. Besides these principal or normal constituents of the granite, tourmaline, garnet, cyanite, and more rarely magnetite and beryl, have been observed. The veins vary in width from a few inches to thirty or forty or more feet; and, although running in a general way parallel with the enclosing schists (interbedded veins) they exhibit a great amount of irregularity, frequently breaking across the bedding of the schists, increasing or diminishing rapidly in thickness, and branching or coalescing, so as to enclose considerable masses of schist. The study of the excellent exposures of these highly feldspathic veins on the ridge throws much light on the structure and general relations of the kaolin under the meadow; for the most casual examination shows, as already stated, that the kaolin has resulted from the decay *in situ* of a vein or a connected group of veins of the pegmatite.

At the eastern base of the ridge, about forty feet from the edge of the meadow, and five to ten feet above the level of the latter, excavation has clearly exposed the contact between the mica schist of the ridge and a broad vein of pegmatite, chiefly feldspar, which extends out under the meadow. The contact is parallel with the bedding of the schist, trending about N. 10° W., and dipping west, or under the ridge, at a very high angle. The schist near the contact is pretty well decayed, falling to pieces readily under the pressure of the hand; but it has not been completely kaolinized or reduced to such a plastic earth as may be seen representing original bodies of schist under the meadow. The pegmatite also, near the contact, and generally above the level of the meadow, is imperfectly decomposed, the decay having advanced to the point of general disintegration without marked or extensive kaolinization. But everywhere below the level of the meadow, so far as seen, the decomposition of both the pegmatite and schist is nearly or quite complete; the abundant gray feldspar of the pegmatite being represented by a beautifully soft and white or occasionally pinkish-white kaolin, which is distinctly plastic when kneaded, and appears to be adapted to almost any of the uses of pure kaolin. The following analysis by Dr. L. M. Norton of the Massachusetts Institute of Technology shows that it has approximately the normal composition of kaolin, and the slight excess of silica may be

reasonably regarded as microscopic quartz existing in the original pegmatite.

Silica (SiO_2)	52.03
Alumina (Al_2O_3)	31.76
Water (H_2O)	15.55
Magnesia (MgO)	0.54
Oxide of iron (Fe_2O_3)	Trace.
Lime (CaO)	Trace.
Alkalies (K_2O and Na_2O)	Trace.
	99.88

That the kaolin has been derived from the pegmatite, and that it is a true case of decomposition *in situ*, there can be no doubt. It still shows throughout the structural features of the pegmatite, including even the form of graphic granite when quartz is present. Half-decayed mica crystals and groups of crystals are seen still undisturbed; but the chief interest in this connection attaches to the scattering crystals of tourmaline. These are sometimes a foot in length; but although rotted to a coarse sand or coal-black earth, they are still essentially intact as to form, and present a sharp contrast to the snow-white enclosing kaolin. Small grains and fragments of half-decayed feldspar are sometimes found in the kaolin; and all these facts, as well as its purity, are incompatible with the idea that the kaolin has been washed into its present position. Again, the partially decomposed pegmatite already noted near the contact with the decayed mica schist on the west, and above the level of the meadow, *appears* to pass gradually *downwards* as well as outwards into the kaolin, the decomposition, as stated, being nearly or quite complete for all that part of the pegmatite below the level of the meadow. And, finally, the relations of the kaolin to the schist prove that it is, as a whole, pseudomorphic after one or more veins of pegmatite. The kaolin has been proved to extend east from the west wall of the vein about one hundred feet, or to the middle of the meadow. It is probably not entirely continuous for this breadth, for on the north side of the excavation, which now affords a good transverse section, the kaolin is divided by a sharply defined and vertical mass of thoroughly decomposed mica schist about eight feet wide. This may be regarded as separating two entirely independent veins of pegmatite; or we may think of the veins as uniting immediately to the southward; or the mass of schist may be simply an enclosure in one large vein of pegmatite. In either case it proves conclusively that the decomposed pegmatite or white kaolin is still *in situ;* for although this schist is

now a soft, unctuous and somewhat plastic clay, glistening with the scales of decayed mica, its original bedded structure is still perfectly preserved; and the idea that it might be a bowlder of schist which had been deposited with the kaolin, or subsequently forced into it by the pressure of the ice-sheet, and afterwards decomposed, is pretty well negatived by the fact that it has the normal strike and dip of the unaltered schist in the ridge. Besides, this mass of kaolinized schist and the adjoining white kaolin differ from the rotten schist and pegmatite along the west wall of the vein, which are unquestionably *in situ*, only in being more completely kaolinized owing to their lower positions. A much smaller mass of kaolinized schist appeared to be wholly enclosed in the white kaolin, but the exposure was not entirely satisfactory. The completely decomposed or kaolinized schist is of a distinctly yellowish to brownish color, owing to the peroxidation and hydration of the iron oxide; and the hornblende schist, as we should expect, yields a more deeply colored clay than the mica schist.

Having seen that both the white and colored clays observed here are the products of decomposition *in situ*, being simply kaolinized pegmatite and schist, and hence genuine examples of sedentary or residual soils, their relations to glaciation and the drift deposits next demand attention. Fortunately, the recent excavation is nearly all that could be desired in this respect. It shows, in the first place, that, although the field under which both the white and brown kaolin are found is nearly level, the upper surface of these residual clays is very uneven; for while they come at some points, as along the west side of the field, nearly or quite to the surface, they are in general covered by greatly varying thicknesses of drift. They have been proved by boring and digging to underlie an area at least one hundred feet in breadth (east and west) and three hundred feet in length (north and south); and in a general way the thickness of the drift increases toward the middle of the field, where it is sometimes as much as ten or twelve feet or more. No prospecting for kaolin has yet been done in the east half of the field; but the shape of the ground is certainly favorable to the view that it is underlaid by the sedentary soils, and it is perhaps probable that toward the eastern, as toward the western, border they come nearest to the surface. It is possible, however, that the rocky ridge rising abruptly eighty feet above the western margin of the field, although its trend is parallel with the glacial movement, has in some way afforded more protection to the residual clays at its base than the low ledges bordering the field on the east.

The drift covering the residual clays is chiefly a dark brown or

slightly greenish-brown sandy clay. It is very compact and firm, a true hard-pan, being in this respect a typical till or bowlder clay, which has felt the full weight and prolonged pressure of the ice-sheet. It resembles the till exposed in various road-side sections in this part of Blandford, except that it is less mixed with stones, being of a more uniform character. It is distinguished from the brown residual clay beneath by its greater hardness, the absence of vertical stratification, the occurrence in it of small, hard, worn fragments of quartz, granite, etc., and especially by the imbedded bowlders. Rounded to sub-angular bowlders one to five or six feet in diameter, consisting largely of fine-grained granite and other rocks foreign to this immediate locality, are scattered over the field or protrude from its surface; and quite a number have been removed from the excavation, while others can now be seen imbedded in the hard-pan clay. A sharp line of demarcation usually separates the hard-pan from the underlying residual clays; and in the north end of the excavation it can be seen to pass unchanged from the rotten pegmatite to the rotten schist. That the drift actually covers the residual clays, and that it is the true till or ground moraine, and not any sort of post-glacial deposit, there can be no reasonable doubt.

The most important question remaining is as to whether the decay of the pegmatite and enclosing schist can be proved to date from pre-glacial times. May we not suppose that the till was spread here, as elsewhere in this neighborhood, over the hard, unaltered pegmatite and schist, and that the decomposition of these rocks has subsequently occurred through the action of some purely local cause? The almost impervious hard-pan would certainly tend to prevent the access of atmospheric agents, and thus protect the underlying rocks here, as it does generally, from decay. The fact that the kaolin underlies what may be called a meadow is suggestive of a recent origin; but although the ground is nearly level toward the northwest, it has a decided slope in the opposite direction, and the whole area is well drained, presenting nothing of a boggy or marshy character. The soil is not peaty, and has all been cultivated. Apparently the only basis for a valid argument against the pre-glacial origin of the residual clays is afforded by the fact that a spring issues, except during the driest months, from near the west wall of the decomposed pegmatite vein, at the base of the ridge, and flows down across the field. The water can be seen coming out through the white kaolin, apparently from a considerable depth. It was the attempt to make this water more available for farm uses that led to the discovery of the kaolin.

The spring, however, is local, while the residual clays, as already stated, have been proved to cover a considerable area, and no known facts forbid the belief that they underlie the entire field or meadow. Excavations and borings, made not only near the spring, but at several points from one to two hundred feet away from it in different directions, have proved that the kaolin extends to a depth of at least twenty-five feet, and that at that depth it is still soft and plastic, affording ground for the opinion that its gradual passage downward into hard rock may not occur nearer than fifty or seventy-five feet from the surface. These dimensions indicate a volume of decomposed rock which it seems unreasonable to attribute to the chemical action of one small spring of cold water in post-glacial times. In fact, considering the acid and stable nature of the pegmatite and schist, we can hardly suppose the meteoric waters to possess this degree of potency even under the most favorable conditions, as when aided by an abundance of decaying vegetation, with the resulting organic acids. The schists about Blandford are rarely stained with iron oxide; and there is no indication that they anywhere contain sufficient pyrite to afford by its oxidation enough free sulphuric acid to be of any interest in this connection.

All these considerations in favor of the pre-glacial origin of the kaolin and decayed schist may, however, be waived without conceding the main point, because the fact that tells most strongly in that direction remains to be stated. The excavation shows that, while the till covering the residual clays is so strongly contrasted with them in character, it yet affords evidence that they were in existence when it was formed. Along the contact between the till and kaolin, the latter bears witness to the pressure and friction of the till, having been dragged along and to some extent mixed with the till; and at some points a vertical section shows several irregular layers or streaks of kaolin alternating with the till, or even a detailed interlamination of the two kinds of material. The structure of the till excludes the free action of water in the arrangement of the materials; but it appears probable that water has co-operated in a partial and limited manner with the ice in developing the rude interstratification of the kaolin and till. At any rate, it is clear that the kaolin antedates, in part at least, the accumulation of the till; and since residual deposits or sedentary soils must grow, in general, from the surface downward, it follows that the oldest part of the kaolin, and therefore the part most certainly of pre-glacial origin, is that on which the till immediately rests.

We are thus forced to the consideration of the problem as to how this limited mass of residual clay, a solitary remnant of the wide-spread sedentary soil of pre-glacial times, has escaped obliteration by the ice-sheet. Apparently, the only favoring circumstance besides the ridge on the west is the fact that toward the north-northwest, where the ground begins to descend in that direction, the schist and granite come to the surface in hard, unaltered ledges, affording, perhaps, a partial protection or lee to the kaolin. We may, perhaps, reasonably suppose that the sedentary soil was originally deeper on this level shoulder of the ridge than on the slopes above or below. There are indications of an unusually large development of pegmatite at this point; and the spring is at least suggestive of fractures, or other disturbance, which would permit freer access of the agents of decay. Although the rational explanation of this seeming miracle of the preservation almost intact of a large mass of pre-glacial soil on a hill-top at an elevation of fifteen hundred feet in the midst of a strongly glaciated region, thus obliges us to postulate conditions more favorable in some respects than have been fully proved to exist, I believe one ventures but little in assuming that, owing to structural features which are not now clearly exposed, the decay of the granite and schist extended here to an unusual depth, so that the lower part of the original thickness of residual clays occupies a distinct recess in the hard, unaltered rocks, which have thus protected and preserved it.

Pre-glacial sedentary soils are, of course, not unknown elsewhere in New England; but the Blandford deposit is perhaps unique in the apparent absence of adequate protection from the erosive action of the ice-sheet, if not in the absence, so far as known, of any specially active or efficient agent of decomposition. The well known deposits of white and colored kaolin in Brandon, Monkton, and other towns in Vermont, are covered by drift accumulations, and certainly date from pre-glacial times. They are, however, closely associated not only with limestone, but also with extensive beds of limonite; and since the iron ore has undoubtedly originated in the pyritiferous schists which often accompany the crystalline limestones of western New England, we find in the free sulphuric acid which necessarily results from the oxidation of pyrite a powerful ally of the meteoric waters in the kaolinization of the schists. Besides, the more important of these masses of kaolin enclose considerable bodies of lignite with vegetable fossils which prove it to be of Tertiary age. These white and colored kaolins are thus seen to be, not residual deposits at all, but aqueous or sedimentary accumulations, perhaps of strictly local

origin, comparable, if not synchronous, with the variously colored clays and associated lignite and iron ore of Gay Head on Martha's Vineyard, and showing even more distinctly the disturbing influence of the great ice-sheet.

At other points in the Green Mountain region the iron ores are accompanied by genuine and unquestionable residual clays; and where the vertical position of the strata has favored the downward progress of the meteoric waters, the decay of the rocks is very far from being a merely superficial phenomenon. Thus, I found on visiting the iron mine in West Stockbridge, Mass., several years ago, that the schists enclosing the ore are thoroughly rotted and kaolinized, even in the deepest workings, about three hundred feet below the surface.

Undoubtedly one of the most considerable occurrences of pre-glacial and strictly residual clays yet observed in New England is that penetrated by the Hoosac Tunnel at the western base of the Hoosac Mountains. The decomposed gneiss and schist here have been called the "demoralized" rock, and added greatly to the difficulty and expense of constructing the tunnel. According to the data collected and published by Dr. T. Sterry Hunt, the decomposed rock has a breadth of fully one thousand feet; and the decay is complete to a depth of at least two hundred feet. In other parts of New England veins of pegmatite are found rotted *in situ*, and affording a pure and white kaolin of commercial importance. But although these may perhaps be fairly regarded as remnants of the pre-glacial sedentary soil, the evidence appears to be less perfect and conclusive than in Blandford.

That the lithologic decay in this region during post-glacial time has been almost *nil* is proved by the fact that the removal of the drift exposes everywhere, and on almost all kinds of rocks, a hard, unaltered glaciated surface. I am well persuaded that even the decomposed dikes of diabase which are observed in many parts of New England, and which are a feature of particular interest in the geology of the Boston Basin, simply witness, in general, to the substantial results accomplished by the quiet and unobtrusive atmospheric agents during the long pre-glacial epochs, and owe their preservation to the narrow fissures which they occupy in harder and more durable rocks. This general conclusion appears to be justified by the fact that the great majority of the dikes present hard, glaciated outcrops; and there is only now and then one which was so deeply decomposed that the ice was unable wholly to remove the products of decay. It is undoubtedly true, however, that the more coarsely crystalline diabase

forming the great dikes in Medford, Somerville, etc., like some of the granites, is subject to rapid disintegration by frost action, and that this process is now going on. We may thus readily explain the formation in post-glacial, and even in quite recent times, of the considerable bodies of coarse diabase sand known in this vicinity as Medford gravel and used for walks and carriage roads. This process is mainly mechanical, and such decomposition as is observed to accompany it may be fairly regarded as incidental, and ascribed to the disintegration which enormously increases the surface exposed to the action of the chemical agents; for it is not intended anywhere in this paper to assign greater efficiency to the delithifying agents or chemical erosion in pre-glacial than in post-glacial times, except as this would naturally result from a milder climate. The climatic difference is undoubtedly of vast importance; but nevertheless chemical changes are now in progress, and, given sufficient time or a sufficiently extended surface for their operation, the results must be comparable in magnitude with those observed in unglaciated regions. The superficial oxidation of the drift is one plain indication that chemical changes are now taking place in glaciated regions, while the *general* absence of sedentary soils simply testifies to the shortness of the time since the ice-sheet melted away.

A COURSE OF INSTRUCTION IN RAILROAD MANAGEMENT.

BY C. FRANK ALLEN, ASSOCIATE PROFESSOR OF RAILROAD ENGINEERING.

IN our best technical schools the instruction in Civil Engineering necessarily includes the study of many subjects which find their most important applications in connection with railroads.

Such instruction, naturally and properly enough, has commonly been directed to the preparation of the student for the work of constructing railroads, — work peculiarly within the province of the civil engineer; if a young engineer can lay out and construct a railroad of any sort, he is of value; if he can be relied upon to construct safely, he is more useful; while if he can also construct economically, his value to a railroad company is wonderfully enhanced.

Safe construction has for many years been taught with considerable completeness, and at the present time the importance of economy in construction is coming to be more fully appreciated, year by year.

The work of the civil engineer is properly construction; but in railroad work a point has already been reached where it is recognized that the best results cannot be attained without taking carefully into account the effect of construction upon the value of the railroad property with reference especially to operating expenses and to earnings. Economical construction, too, depends not merely upon proper design, but equally upon skilful business management in the execution of the work. From these and other causes, it has resulted that there is demanded from railroad engineers a broader knowledge of many questions connected with the administration and operation of railroads than that which naturally results from instruction in civil engineering, technically considered.

This demand may very properly be met by a course of instruction in Railroad Management, which, however, should not be too strictly limited to the matters above specified, and, in fact, ought not to be confined to the needs of students of civil engineering, or even of young men whose life is to be devoted to railroad work; for railroads are so closely identified with nearly every interest of our country that some knowledge of methods of administration ought to be of interest

and value to every one. If we consider railroads in their various relations to their owners, to their patrons, to their employees, and to the government, we are enabled to gain some idea of the breadth of the subject. Within a few years, the relation of the railroads to the government has assumed more than ordinary importance, and not a little legislation has resulted, having in general for its object, in this country, the protection of the public against any unjust action on the part of the railroads. In fact, the importance of the relation of railroads to the government as a public question has far outstripped the ability of legislators or of citizens to deal wisely with it, and there exists a definite need of growth and development in knowledge of railroad matters among our better educated citizens.

A course of lectures in Railroad Management in a technical school should then be arranged not alone with a view to the better fitting of students for railroad work; it should equally be considered as a branch of liberal education leading to a broader and better citizenship.

It is proper that such a course should presuppose some knowledge of Political Economy, and that it should be treated largely from the economic side. Matters of minor detail should have no place there, except so far as they can be advantageously used in illustration of some principle.

It matters little to us whether a brakeman raises and lowers his lantern, or swings it in a circle, for a signal to an engineer to start or stop a train. There is no matter of principle involved. It might be entirely proper, however, to point out, as a matter of principle, that it is bad management in the case of two neighboring roads that a brakeman on one should raise and lower his lantern, while on the other the brakeman should swing his in a circle, to indicate the same train movement.

At the outset, a brief history of railroads from the beginning may well serve as a foundation upon which to build, and this may profitably be followed by a discussion of the means for internal commerce that existed a century ago, and the progressive steps, including turnpikes and canals, by which railroads became the recognized channels for all long distance inland traffic. The causes and conditions which led to the consolidation of short independent lines into systems for through traffic would naturally follow, and bring us to the consideration of what a railroad is at the present time, as a basis upon which more readily and understandingly to investigate those general railroad questions and problems which should constitute the most important feature of such a course.

In a lecture delivered a few years ago, Charles Francis Adams divided railroad administration into five principal departments: 1. Financial; 2. Construction; 3. Operating; 4. Commercial; 5. Legal; — a classification very convenient for our use.

In the Financial Department, the first question is, properly, whether or not to build the line, and its answer should depend upon the probability of its yielding a profit to its projectors; but this profit may be in the form of an indirect return. A discussion of the nature of a railroad corporation, how formed, how the money is secured, and how spent, will shed much light upon the methods by which profit may be secured; such a discussion should show, for instance, what is the nature of the stockholder's interest in a railroad, and why, in a new and growing country, the proportion of bonds to stock should be large, while in a well settled region, where capital is abundant, the proportion of bonds to stock is likely to be small. Statistics may be given, showing the amount of money invested in railroads; showing, in the case of certain railroads, how much of gross earnings is absorbed in operating expenses, how much goes to interest on bonds, and how much to dividends; giving, also, general data as to the amount of dividends paid, and the proportion of bankruptcies and receiverships. The business conditions which have led to the necessity for corporations rather than partnerships are worthy of attention. Reference should be made to speculation and speculative management, and to stock watering in its several forms, some of which are unobjectionable in point of morality, while others are bad enough. It should also be shown in what way accounts are juggled so that dividends may be declared when none have fairly been earned. These and many other matters form suitable subjects for discussion in considering this department.

The Department of Construction is that in which civil engineering finds its special field. The first question to be decided upon is the route, and it is desirable that the general route shall be settled from an actual examination of the country, previous even to the drawing of the charter. An unfortunate selection of location means, perhaps, steeper grades, lighter trains, and increased expense of operating; it may mean largely increased cost of construction, or a failure to reach important points from which large earnings ought to have been secured, or it may, indeed, involve the company in serious legal complications. An inferior location may handicap the work of each of the other four departments. The attention of the student should be called to such facts, and he should understand that

in construction it is often, though not always, the case, that economy will result from building cheaply at first, and renewing or improving in a more permanent manner at a later date. As an example, bridges of minor importance may be first constructed of wood, and, when renewal is necessary, replaced by structures of stone or iron, which can be hauled by train much more cheaply than by wagon. Embankments, too, may be left low at first, and afterwards raised when steam-shovel and train allow of very cheap handling of material. These matters touch closely, perhaps, upon the technical in civil engineering; but, in addition, there are matters purely of business management, among the most important of which are the letting of contracts and dealing with contractors. There is opportunity for much to be said as to whether a large amount of work should be let under a single contract, or whether in short stretches of a few miles each; then the manner in which specifications shall be drawn, including the basis for estimating the work, may noticeably influence the price of bids, while the personal characteristics of the chief engineer will often affect the cost of work to a considerable extent. The purchase of material, again, offers more than usual temptations to waste. A careful discussion of such questions as those mentioned above is believed to be of the highest interest and importance, and practically outside the matters properly or generally taught as a part of civil engineering.

The Operating Department might, with propriety, include the Commercial; but it is more convenient to separate the two, regarding the operating department as looking after the running of trains, and, for a rough classification, the conduct of those affairs in which expenses are incurred, while the commercial department attends to the securing of business, and deals largely with matters of receipts or revenue. Taking the operating department proper, it was found that, as the business of railroads increased in importance, a superintendent could have personal knowledge of but little of the actual detail work, and as the number of employees became greater, and the duties more varied, the necessity for organization became apparent, and now organization thorough and complete has become a very important feature of railroad operation. A schedule of organization should be given, showing a complete system, from the Board of Directors and the President down to the brakemen, section hands, and day laborers. Much light can be shed upon the operation of a railroad by devoting some attention to the character of the duties of many of the officials whose work is important, though not understood or appreciated by the general public; among these may be mentioned, for example,

the auditor, the purchasing agent, the car recorder, the train despatcher, and, perhaps, the more humble hostlers and track-walkers. The organization and discipline of the working force, the methods of payment of trainmen, the adjustment of lengths of divisions and of train-crew runs, the weight of engine, the capacity of cars, the operation of pusher grades, the best business methods for maintaining good track, the weight and general form of rail in case of renewal, — these and similar questions have bearing upon the cost of operating, sufficient to deserve special comment, or, in some cases, detailed explanation. It is, in short, desirable to touch upon various minor matters not evident to the looker on, which are, nevertheless, important links in the successful operation of a railroad. The value and use of railroad statistics are matters of great importance, and may be properly considered at this time.

The Commercial Department, as has been already stated, is concerned in securing business, and deals with receipts and revenue. No railroad can be managed profitably simply by economy in operating; it is necessary that the securing of revenue should have very careful attention, in order that the gross earnings may be as large as possible. We should know from what sources railroad receipts are derived, and should understand the general principles upon which success in securing them depends; it should be pointed out that in some cases larger returns can be expected to result only from the development of the country traversed by the railroad; in others, the expenditure of effort should be in an attempt to outdo rival lines. There is an excellent opportunity here to show the student the necessity of recognizing that in many cases the prosperity of the railroad is dependent upon the prosperity of the country, and that this prosperity depends largely upon the facilities and encouragment offered by the railroad itself. The interests of the public and of the railroads are largely identical, a fact which the most enlightened railroad managers have long since learned. Either here or elsewhere some mention should be made of the methods adopted for conducting through freight traffic, including some discussion of car "mileage" and "per diem," of classification of rates, of differentials, and various other matters of interest of a similar character.

The Legal Department is not of a character to require that much time should be devoted to a description of its work. It is, however, very desirable that the student should know what constitute the principal duties of a railroad attorney; that the preparation of charters, leases, contracts, and deeds, and the private settlement of claims are

far more important parts of the railroad lawyer's work than the mere trial of cases. The young engineer should, if possible, know something of the legal difficulties to be avoided in the conduct of his own work, and have some idea as to when it will be necessary for him to consult the company's lawyer in order to avoid trouble. While a discussion of the legal department proper does not justify the expenditure of much time, yet an admirable opportunity is presented for giving the student some instruction in such points of law as have a direct bearing upon the conduct of railroad business. Some knowledge of law is desirable for every business man. There are few who do not find it necessary to make contracts of some sort, even if verbal only, and every one ought to understand what features are essential to a valid contract, and, in addition, to know what other provisions good business principles dictate as requisite. Of other law, it is well to dwell somewhat upon such matters as the distinction between common and statute law; between questions of law and questions of fact; the law of common carriers; the law of eminent domain; the essentials of a deed for the transfer of real estate. The instruction in these matters should be brief, and should not involve the technicalities proper for law students; the general principles, however, can and should be set forth in a way to be understood by any student of average intelligence, and sufficiently to enlarge materially his intellectual horizon.

A sufficient foundation should by this time have been established to allow of the profitable consideration of general matters affecting railroad administration. Such for instance, is the principle of competition and combination, applied generally, as well as to railroads; but it should be pointed out that the operation of competition and combination is different in the case of railroads on the one hand, and of general business on the other. The several kinds of monopoly may be referred to and commented upon. The methods adopted by railroads to avoid the evils of competition should be carefully looked into, and this should lead to a discussion of railroad associations and railroad pools. It is desirable to allude to the important changes in business methods which have taken place since railroads were first introduced, what these changes have been, and how they have led to lower rates, — rates low enough to admit of the railroad largely superseding the canal. The methods adopted in making rates, partly in classification, have also led to discriminations of various kinds; and it is upon the matter of discrimination that public interest in railroad affairs has very largely centred. It readily can be, and it should be,

shown that railroad profits are not on the average too great; that railroad charges are not in this country too high; and that the widespread dissatisfaction which has at times been prevalent has been due to discrimination of some sort.

For the evils that have existed many different remedies have been proposed, and a few have been tried. Much that is desired has been reached in some cases by State Railroad Commissions, while in other cases direct legislation, some of it of the "Granger" type, has been resorted to with varying success; various degrees of government supervision and regulation have been attempted, and in foreign countries government control and management have been resorted to; a full discussion of these matters is of extreme importance. In our own country a peculiar difficulty has been experienced, owing to the fact that the separate States could control matters only within their own limits. The outcome has been the passage, within a few years, of the "Interstate Commerce Act," which has naturally and properly attracted public interest more fully than any other railroad matter.

The Interstate Commerce Act should be made the subject of careful and detailed study, and attention should be called to the evils which led to its passage, to the provisions by which those evils were sought to be remedied, and, also, to other provisions adopted for the purpose of rendering the act practically effective. The observed effects of the law in various ways may also be discussed to advantage. In fact, the general discussion of railroad problems can be arranged, very interestingly, in such a way as to lead up to and find its culmination in a thorough discussion of this law in all its bearings. A full appreciation of the points involved cannot well be secured except by a previous understanding of the points developed under the heads of the different departments, including the legal instruction, and very clearly requiring that the student should understand the bearing of competition, discrimination, government control, and all such questions, with reference to this law.

There are also many subjects that may be either treated as isolated subjects, or incorporated in the general discussion, as seems best. The question of taxation is one of some difficulty in any case, and as applied to railroads some unusual methods have been adopted. The ordinary basis, upon real estate and personal property, is not uncommon; but in some States the capital stock forms the basis, while in others the tax is a certain percentage of the earnings; so that, from the variety of views entertained, the subject of taxation of railroads becomes an interesting and important one.

Railroad accidents can be discussed, and statistics given to show their causes and furnish means for judging in what ways we may expect to avoid them, or render them less disastrous when they occur.

It is but a few years since narrow gauge railroads were in great favor, and a discussion of the merits of the narrow gauge, as compared with the standard gauge, may as properly find its place here as in the technical work of railroad engineering.

From time to time, also, there arise questions having temporarily special importance, and requiring on that account more than passing notice. Such, for instance, at the present time in Massachusetts, is the question of the abolition of grade crossings, where every one wants grade crossings done away with provided some one else will pay for it.

The subject of Railroad Management is so broad, that, in arranging a course of lectures upon this subject, there is as great difficulty in knowing what to exclude as in deciding what to include. It is not improper to repeat that the subject should be treated in general from the economic standpoint, and should, it is believed, deal little with details, except for the purpose of illustrating principles, unless perhaps in some cases where it is desirable, or almost necessary, in order to maintain the interest of a class.

The Course of Instruction in Railroad Management above outlined is essentially the one given to students at the Massachusetts Institute of Technology, and has been primarily arranged with a view to the needs of young men whose future will be identified with railroad work. Railroad administration furnishes abundant opportunities for any well educated young man to exercise all the ability which nature and training have placed at his disposal, and a technical training is without doubt the best foundation upon which to build, in anticipation of entering the service of any of our successful railroads. But the importance of the relation of railroads to the State, which is becoming more evident almost day by day, furnishes a reason why a course differing little from the above might with propriety be looked upon as a useful part of a liberal training in colleges where instruction in technical engineering finds no place.

THE DISTRIBUTION OF PHOSPHORUS AND NITROGEN IN THE PRODUCTS OF MODERN MILLING.

BY ELLEN H. RICHARDS, INSTRUCTOR IN SANITARY CHEMISTRY, AND LOTTIE A. BRAGG, S. B.

THE wheat product of the United States is now about 500,000,000 bushels annually, while the production of Indian corn is nearly four times this amount. The wheat is mainly used for human food, while Indian corn is largely fed to animals, so that whatever concerns the best use of wheat concerns the human race. Whole wheat has long been considered one of the few perfect foods containing all the elements necessary to healthful life. When the law of civilization (division of labor) required the large mill to replace the family mortar, it became essential to prepare a flour which would bear transportation from the place of manufacture to the place of use. This requirement could be met only by the removal of the germ and the outer coating of bran, both of which contain certain active ferments, which soon begin to act upon the starch, and so cause the flour to spoil. In order to secure the keeping of the prepared flour for an indefinite time, it was necessary to remove both these substances by a process of sifting or bolting.

After chemical analysis showed the germ to be the richest in nitrogenous substances of any part of the grain, and the bran to be richest in phosphates, it was cleverly argued that the sifted flour had lost its high character as a food, and for the past forty years or more white flour, and white bread made from it, have been the targets at which all food reformers have levelled their arrows.

A measure of opprobrium lingers long after the cause of it has been removed. Although the whole process of flour manufacture has undergone a revolution since 1872, and roller milling has, in the larger establishments at least, taken the place of horizontal stone grinding, and thus the character of the products has been materially changed, the same old arguments still serve, and the same abuse of white bread is found in all books upon food.

It was our intention to compare the products of the two processes as to the per cent of phosphorus and nitrogen in the finer grades of flour; but on consultation with the Flour Inspector of the Boston

Chamber of Commerce, Mr. Towne, we found to our surprise that no mills of any considerable size were using the old stones alone, although a few mills were known to use a combination of both methods. Inquiry in all directions failed to bring to our knowledge even a small country mill turning out the old ground and bolted flour, so complete has been the revolution accomplished in eighteen years.

It was then determined to endeavor to obtain a comparison of flour made from winter wheat and from spring wheat, not only as to composition, but as to distribution of the important elements in nutrition.

We are indebted again to Mr. Towne and to Mr. J. O. Frost for the suggestion of the names of manufacturers whose reputation for progressive spirit and scientific method could be counted upon to respond to our somewhat troublesome request, which was nothing less than a set of samples guaranteed to be fair averages of a lot of wheat and of the products of milling, and also the per cent of each product, in order that we might construct a balance sheet of the phosphorus and nitrogen, and determine its proportionate distribution in the various products.

Well aware that this was a great deal to ask, we preferred our request, with some misgivings, to Messrs. E. T. Archibald & Co., of Dundas, Minnesota, for samples of spring wheat, and to Messrs. E. O. Stannard & Co., of St. Louis, for samples of winter wheat. Both these firms responded with the greatest courtesy and cordiality, and we take great pleasure in acknowledging our indebtedness to them.

Since these samples are from mills not included in the Bulletin of the Department of Agriculture, "An Investigation of the Composition of Wheat and Corn," by Clifford Richardson, the results have an additional value.

The samples came directly from the mills, in little sacks carefully protected, and were put into tightly closed jars as soon as they reached the laboratory.

The samples of St. Louis winter wheat comprised

Whole Wheat,	Low Grade Flour,
Royal Patent Flour,	Middlings,
Extra Fancy Flour,	Bran.

The samples of Minnesota spring wheat comprised

Whole Wheat,	Low Grade Flour,
Patent Flour,	Shorts,
Bakers' Flour.	Bran.

Five determinations were made of the weight of each wheat, the average result being: —

100 grains of St. Louis Wheat weighs . . . . . 2.64 grams.
100 " Minnesota " " . . . . . 2.74 "

The analytical work consisted in the determination of the moisture, nitrogen, and phosphorus in all the samples.

The nitrogen was determined by the Kjeldahl process, as follows: —

The flour was weighed out in a small tube with a loop of platinum wire fused in the end of the glass, so that, when weighed, it could be lowered into a pear-shaped digestion flask without leaving any flour on the neck of the flask. Ten cubic centimeters of strong sulphuric acid were then added, and from 0.25 to 0.3 gram of pure mercury. The flask was placed over a low flame and digested until the solution was colorless. At this stage a few crystals of potassium permanganate were added, until a green color remained. When cool, the contents of the flask were transferred to a round-bottomed flask, using 200 c.c. of water free from ammonia to rinse the flask well. Then 15 c.c. of potassium sulphide solution were added, and lastly 80 c.c. of caustic soda, washing down the neck of the flask with water free from ammonia. The flask was then connected with a proper condenser. Twenty-five cubic centimeters of standardized hydrochloric acid solution were run from the burette into a 250 c.c. receiving flask, and water added, if necessary, to seal the exit tube of the condenser, which was of glass with a bulb at the top. About 200 cubic centimeters were distilled off. Into this was run from a burette enough ammonia solution to make it alkaline, as shown by the yellow color of the solution from the methyl orange, a few drops of which had been added. This alkaline solution was then titrated with standard hydrochloric acid solution, to the exact point of neutralization. The flask was saved, and the color of this used as a standard in titrating the duplicate.

The following are the results obtained by this method.

NITROGEN DETERMINATIONS IN MINNESOTA SPRING WHEAT AND ITS PRODUCTS.

	No. of Determinations.	Nitrogen. Average per cent.
Whole Wheat	5	2.236
Bakers' Flour	7	2.403
Patent Flour	9	2.099
Low Grade Flour	8	2.594
Shorts	8	2.784
Bran	6	2.552

NITROGEN DETERMINATIONS IN ST. LOUIS WINTER WHEAT AND ITS PRODUCTS.

	No. of Determinations.	Nitrogen. Average per cent.
Whole Wheat	6	1.875
Extra Fancy Flour	6	1.787
Royal Patent Flour	7	1.396
Low Grade Flour	5	2.084
Middlings	6	2.738
Bran	6	2.622

To determine the moisture in the wheat and flour several methods were used, with varying success. It was first attempted to dry the samples in tubes made from test tubes, which fitted closely so as to make a nearly air-tight joint. The tubes were placed in a sack which held the covers also, and dried at 110° C., and cooled over calcium chloride. The results were uniform, but in all there was a gain at the third or fourth weighing. After some experiments in drying in an atmosphere of hydrogen, it was decided to adopt an arbitrary method mentioned in one of the Bulletins of the Agricultural Department.

The sample was weighed between watch-glasses, the cover and clip were removed and left in the desiccator, while the flour was put in the hot closet for two hours, then taken out, covered, and cooled in the desiccator for fifteen minutes, weighed, the cover removed, and put back for half an hour. This process was repeated until a constant weight was obtained or the flour showed signs of oxidation. With this conventional method good agreeing results were obtained.

MOISTURE IN ST. LOUIS WHEAT AND PRODUCTS OF MILLING.

	Per cent.
Whole Wheat	12.85
Extra Fancy	12.51
Royal Patent	13.37
Low Grade	11.94
Middlings	11.21
Bran	12.15

MOISTURE IN MINNESOTA WHEAT AND PRODUCTS OF MILLING.

	Per cent.
Whole Wheat	11.09
Patent	12.29
Bakers'	12.14
Low Grade	11.47
Shorts	11.27
Bran	11.23

In the determination of phosphorus in wheat, there has often been doubt expressed whether the phosphorus found in the ash represents the total phosphorus in the wheat. The possibility of losing phosphorus in the incineration naturally suggests itself, but no experiments have been made, as far as we know, to determine whether there was actually any loss under these conditions.

A large number of phosphorus determinations were made on the same sample of flour, by treatment with nitric acid and by fusion with acid potassium sulphate. The results thus obtained were not found to be higher than when the ash of the flour was used, showing that there is no loss in the incineration.

Following are the methods and results of this investigation.

About 2 grams of the flour were heated in a covered beaker with nitric acid of 1.4 sp. gr. until the residue of the evaporation was white; this required many hours, and a large excess of nitric acid. This white residue, dissolved in nitric acid, was precipitated by ammonium molybdate, and the solution of the yellow precipitate treated, as usual, by magnesia mixture.

In the bisulphate process, 2 grams of the flour were intimately mixed with 50 grams of potassium bisulphate, in a large platinum crucible, and a layer of the bisulphate put on top of the mixture. On heating the crucible for about twenty minutes with a good Bunsen burner, the flour is completely burned, and a perfectly white mass remains. This is porous, and disintegrates and dissolves readily in water. To the watery solution was added, when boiling, 20 c.c. acetic acid 1.04 sp. gr., 25 c.c. ammonia 0.96 sp. gr., and 5 c.c. of a solution of ferric chloride containing about 10 milligrams of metallic iron to the cubic centimeter. The precipitate of basic ferric acetate containing all the phosphoric acid was filtered off (after settling), dissolved in nitric acid, and the phosphoric acid precipitated by molybdate solution. A blank analysis gave the phosphoric acid in the reagents used.

The ash of the flour was obtained by igniting in a platinum dish in a muffle, or over a Bunsen burner. The ash was fused with a little sodium carbonate, the silica separated by evaporation with hydrochloric acid, and the phosphoric acid precipitated directly by magnesia mixture, using a little nitric acid to keep up any iron or alumina that might be present.

The results obtained by these processes on a sample of "pastry" flour, source unknown, were as follows: —

	Per cent of Phosphorus.		Per cent of Phosphorus.
Nitric Acid Method,	0.13	Ash,	0.12
" "	0.13	"	0.11
" "	0.13	"	0.11
" "	0.13	"	0.12
Potassium-bisulphate Method,	0.12	"	0.11
" " "	0.11	"	0.12
" " "	0.11		

The following tables give in a condensed form the results of the analyses of the two samples of wheat, and the products derived from them, and a balance sheet deduced therefrom.

ST. LOUIS WINTER WHEAT. MINNESOTA SPRING WHEAT.

	Water.	Phosphorus.	Nitrogen.		Water.	Phosphorus.	Nitrogen.
	Per cent.	Per cent.	Per cent.		Per cent	Per cent.	Per cent.
Whole Wheat	12.85	0.262	1.87	Whole	11.09	0.230	2.24
Royal Patent	13.37	0.051	1.39	Patent	12.29	0.050	2.10
Extra Fancy	12.51	0.100	1.78	Bakers'	12.14	0.091	2.40
Low Grade	11.94	0.100	2.08	Low Grade	11.47	0.192	2.59
Middlings	11.21	0.225	2.73	Shorts	11.27	0.560	2.78
Bran	12.15	0.828	2.62	Bran	11.23	0.830	2.55

BALANCE SHEET.

ST. LOUIS WINTER WHEAT.

	Pounds.		Pounds of Phosphorus.		Pounds of Nitrogen.	
Whole Wheat . .	....	100	....	.262	....	1.87
Royal Patent . . .	22.72	....	0.0116	....	0.3158	....
Extra Fancy . . .	39.76	....	0.0397	....	0.7077	....
Low Grade . . .	8.52	....	0.0085	....	0.1772	....
Middlings	3.26	....	0.0073	....	0.0889	....
Bran	24.47	....	0.2066	....	0.6411	....
Total . .	....	98.73	....	.273	....	1.93
			Per cent of total Phosph.		Per cent of total Nitrog.	
In the three grades of Flour	....	....	22.2	....	62.2	....
Middlings and Bran	....	....	77.8	....	37.8	....

MINNESOTA SPRING WHEAT.

	Pounds.		Pounds of Phosphorus.		Pounds of Nitrogen.	
Whole Wheat . .	....	100	....	.230	....	2.24
Patent	51.50	....	0.0257	....	1.0815	....
Bakers'	17.50	....	0.0159	....	0.4200	....
Low Grade . . .	3.50	....	0.0070	....	0.0906	....
Shorts	11.00	....	0.0616	....	0.3058	....
Bran	15.50	....	0.1286	....	0.3952	....
Total . .	....	99	....	.238	....	2.29
In the three grades of Flour	....	....	Per cent of total Phosph. 20.4	....	Per cent of total Nitrog. 69.5	
Shorts and Bran .	....	....	79.6	....	30.5	

This balance sheet defines the position of fine white flour very clearly. It shows that hard spring wheat gives a flour rich in nitrogen, 69.5 per cent of the total being saved in the three grades of flour. Winter wheat does not show quite as well: not only is there more bran, but it is richer in nitrogen. Nevertheless 62.2 per cent of the total nitrogen is saved. There is, therefore, no need to eat whole wheat bread in order to obtain a food rich in nitrogen.

Quite another story is told by a study of the proportion of phosphorus. The two varieties of wheat more nearly approach each other, but the spring wheat loses 79.6 per cent, and the winter wheat 77.8 per cent of its total phosphorus. Here then, is the bone of contention. The fine white flour is sadly deficient in phosphorus, but is the phosphorus which is contained in the bran available for human food? According to the latest experiments of Professors Voit and Rübner in Munich, it would seem that not only is the bran quite indigestible, but that by its irritating action it causes a loss of both nitrogen and carbo-hydrates which would be available in its absence.

It would seem, therefore, fair to conclude that the bread made from fine flour which is most tempting to eyes and palate may, after all, be the one best adapted to the needs and conditions of the human system.

THE LILY DISEASE IN BERMUDA.[1]

BY ALEXANDER L. KEAN.

In the winter of 1888, through the kindness of General Russell Hastings of Hamilton, Bermuda, I had the opportunity of investigating a disease, epidemic in the lily fields there from March to July. Diseased specimens had previously been shown to several naturalists who had visited Bermuda, and a few of the same had been sent to the United States for examination. None of those who saw these specimens were able, upon a merely cursory examination, to identify the disease; so that the subject still remained open for investigation.

Towards the end of February I sailed for Bermuda, in order to observe personally the phenomena attendant upon the first stages of the disease, which usually begins early in March. A few words on the cultivation of the lily in Bermuda and upon the history of the disease may not be out of place.

The industry is a comparatively new, but prosperous one, being only a few years old. The lily cultivated is the so called Lilium Harrisii, a dwarf variety of Lilium longiflorum. This variety has been propagated from year to year by bulb scales and by a few plants raised yearly from seed. The latter are always more vigorous than those raised from bulb scales; they tend, however, to return to the original longiflorum type. The bulbs, planted in the early autumn, grow throughout the winter months and flower in the spring. They are taken up again early in the summer, and shipped to the United States, where a good market is also found for the flowers in the spring months. The lilies are planted in rows, in small fields; these fields are surrounded by high oleander hedges, which serve to protect the plants from the wind.

So far as I know, the lily disease was first noticed about 1885, since which time it has yearly become more serious, until at present it threatens to do serious damage to the lily crop. It makes its appearance in the spring, when the days begin to grow warm. The marked difference in the temperature between day and night results in a heavy fall of dew, so that even after the sun is high in the heavens large dew-drops may be found upon the lily leaves. A little

[1] Reprinted from the Botanical Gazette, January, 1890.

cool weather, or a few warm, dry days free from dew, will check the activity of the disease, while a warm, damp day will cause it to spread with great rapidity. The disease first appears as a minute orange-colored spot upon a leaf or flower, usually on the upper side of the leaf. Figure 1 (*a*) shows an early stage. The spot gradually increases in size, and finally spreads throughout the whole leaf. In this way whole plants may be killed, and only the stalks left standing. It is not unusual to find several of these spots on the same leaf, as in Figure 1. If, for any reason, the progress of the disease is checked, these become dry, leathery patches of a buff color.

It was thought possible, by some of those who had seen the diseased specimens, that the spots might be due to the stings of insects. Though at first this did not seem unlikely, a closer acquaintance with the disease rendered it highly improbable.

Sections of the spots examined under the microscope revealed nothing more than that in the diseased area the structure of the leaf had collapsed; while along the edges of the spot the cells were somewhat swollen and the cell walls thickened. The cell contents were slightly shrunken, and contained a number of bright dots, which did not stain with the ordinary reagents. In a few cases where specimens were teased, an occasional hypha of a fungus was found, which, however, might easily have come from external contamination. In a slightly more advanced stage of the disease, hyphæ of a fungus might be found ramifying through the soft decaying tissues, the gonidiophores appearing on the surface (Fig. 2).

This fungus invariably appears in advanced stages of the disease; moreover, it is always the first to appear. Other fungi, such as Macrosporium, Eurotium, and Penicillium, also appear on the decaying leaves, but this fungus invariably precedes all others. At the same time, as it could never be found until the tissue had become pretty thoroughly rotten, it seemed at first sight to be rather a consequence than a cause of the disease.

Early in April I was obliged to return to the United States, and for a time my investigations were interrupted, to be resumed again in the summer, when I had specimens forwarded to me from Bermuda. It had seemed possible that the disease might be due to bacteria, on account of its peculiarly rapid growth and its susceptibility to climatic conditions, as well as for other reasons. Accordingly a series of cultures in nutrient gelatine and agar-agar was begun. By this method two distinct species of bacteria were isolated from the spots, either of which might have been the cause of the disease.

Inoculations were attempted, both in the laboratory and in the garden, all of which failed to produce the disease; but as the American climate is dry, and therefore unfavorable, it was thought that the bacteria had not been given a sufficient trial, and so it was decided to let the whole matter lie over until the next winter, when inoculation experiments could be made in Bermuda.

Shortly before visiting Bermuda for the second time, my attention was again directed to the fungus as a cause of the disease by the appearance of Professor Marshall Ward's description of a similar disease caused by a fungus growing upon the Lilium candidum in England. Upon my arrival in Bermuda, in February, 1889, I renewed my efforts at inoculation with bacteria, but in every case without success. I also placed a number of plants in glass jars which contained fluid cultures, to see if by any chance the action of bacteria upon the bulb might not have something to do with the epidemic. These plants, however, remained remarkably healthy, as did also a number of plants from which I removed the bulbs, placing the stalks in fluid cultures, so that the bacteria had direct access to the tissues of the plants. The weather was extremely unfavorable, so that, although I saw numerous small spots, I met with none large enough to show gonidiophores of the fungus. I was therefore unable to complete my experiments satisfactorily in Bermuda, as I could not even get a culture of the fungus as a starting point. Since my return, however, I have had specimens sent to me and have been able to carry on a series of experiments in the laboratory, by means of which I have at length ascertained definitely the cause of the disease. Meanwhile I have repeatedly tried to inoculate plants in the laboratory with bacteria, all of which attempts have been signal failures, as have been, likewise, all attempts to produce the disease by fungus spores sown in a drop of Irish moss which had been placed upon a leaf. In the latter case it was found impossible, without resort to artificial means, to keep the air of the room moist enough to prevent the drop of Irish moss from drying up soon after it was put upon the leaf. I readily succeeded, however, in getting numerous Irish moss cultures of the fungus, and I have also grown it in water, both ordinary and sterilized, and in hanging drops as well as in drops merely placed upon a slide.

In my next experiments, leaves freshly picked from the plant were used and kept fresh in a beaker of water, which was placed under a bell glass where there was a second beaker of steaming water, which was occasionally renewed so that the atmosphere was kept warm and moist, thus making the conditions highly favorable. Bacteriological

experiments under these conditions failed as had all previous experiments. On the other hand, experiments with the fungus were entirely successful. If a drop of Irish moss placed on the surface of a leaf is inoculated with spores of the fungus mentioned above, a disease spot will appear in about two days, unless in some way the drop has dried up, or been otherwise disturbed. If the drop has simply dried up, it is only necessary to moisten it again and the spot will soon appear. About the third or fourth day the gonidiophores appear and soon bear compact bunches of gonidia, the whole forming a downy growth on both sides of the leaf. It makes no difference whether the original spores are sown in a drop on the upper or the under side of the leaf. In either case the disease is produced. I have substituted drops of water for the Irish moss as a culture medium with equal success, and, to exclude contamination, drops of sterilized water were used, with which I also obtained excellent results.

To prove beyond all doubt that the fungus is the cause of the disease, the following experiment was made. Into a tube of sterilized nutrient gelatine some fungus spores were introduced on the tip of a sterilized needle. The contents of the tube were then "plated" according to Koch's method. The fungus grows luxuriantly in this medium, and can thus be obtained free from bacteria or other fungi. Spores are less quickly produced on the rich gelatine than on the comparatively poor Irish moss. Inoculations made with spores from a pure culture of this kind readily produced the characteristic spots, while blank control experiments showed nothing whatever.

The fungus appeared to me to be identical with the Botrytis recently described by Professor Marshall Ward[1] as growing upon the Lilium candidum in England, and from a specimen sent to him Professor Ward has identified it as the same. So far as I know, the Lilium candidum is exempt from the disease in Bermuda, but this species is only occasionally grown there, and then with only a few together. Under similar circumstances the longiflorum also is generally exempt, the plants in the fields alone suffering. The true longiflorum is not considered to be as susceptible to the disease as the Harrisii. Since Professor Ward has described the Botrytis and its method of growth in so complete a manner, it would be superfluous for me to enter upon a detailed description of it. I shall, therefore, give but a brief summary of the main facts in its life history, as I have observed them.

[1] A Lily Disease, by H. Marshall Ward, M. A., F. R. S., F. L. S. Annals of Botany, Vol. II. No. 7, November, 1888.

The gonidia are ovoid in shape, about 0.02 mm. long and about 0.015 mm. broad. They are at first colorless, but when mature are light brown, the whole gonidiophore passing through the same change of color. The gonidia are attached to the gonidiophores by means of slender sterigmata. These sterigmata are frequently found still adhering to the spore after it is entirely separated from the gonidiophore upon which it grew. While the normal shape of the spore is ovoid, spores are often found of different shapes, as those depicted in Figure 7. These forms, however, seem to belong to the period of germination, being simply conditions which the gonidia assume in the process of swelling. The spores are almost always ovoid, although in some old bunches they may sometimes be elongated, and even divided by a partition. In germination, the gonidium swells, the protoplasm becoming quite dense. Soon after, the wall begins to bulge out in several places, from which hyphæ are eventually protruded. One of these is generally more vigorous than the others, and grows much more rapidly, producing a complicated mycelium, while the other hyphæ are scarcely more than buds. The protoplasm of the rapidly growing tips of the hyphæ is quite dense, while that in the older hyphæ is clear and much vacuolated. Two remarkable features of the mycelium described by Professor Ward I have also observed. These are, first, organs of attachment, consisting of thick cone-shaped tufts (Fig. 5), developed upon the hyphæ when they come in contact with any foreign body which they are not able to penetrate. The second peculiarity is the development of cross branches between contiguous hyphæ, thus forming a network in the mycelium (Fig. 6). The gonidiophores are, on the leaves, as a rule, about one millimeter in height. When they reach this height, their tips begin to swell and numerous small peg-like processes appear upon the heads thus formed. These are the sterigmata, and on each of these a gonidium is formed (Fig. 3). There are seldom fewer than four gonidia in a head and they usually bear a much larger number. With perhaps thirty of these heads to the square millimeter, which is about the average number on an ordinary diseased leaf, it is not strange that, under favorable conditions, the disease should spread from leaf to leaf and from plant to plant with surprising rapidity. If the growth of the fungus is unchecked, the erect hyphæ may bud out just below the gonidiophores, and, after growing a short distance, produce another bunch of gonidia, and so on, thus forming a series such as is shown in Figure 4.

In this disease the fungus does not grow in the sound tissues of the host, extracting nourishment from them, but the spores, germinating

upon the surface of the leaf, in some way macerate it. According to Professor Ward, this is done by means of a ferment secreted by the tips of the hyphæ. I have not as yet been able to experiment upon this ferment; but I have seen nothing to invalidate his view. The cell walls having been softened, the hyphæ pass through them, ramifying amongst the decaying tissues of the leaf.

The principal conclusions arrived at in this paper are the following: —

1. A disease, hitherto unexplained, and threatening to become a serious epidemic in the lily fields of Bermuda, has been assigned to a definite cause.

2. There is no evidence that the blight is due to the stings of insects.

3. There is no evidence that the disease is caused by bacteria.

4. There is strong evidence that the disease is caused by a fungus, growing upon and within the leaves or flowers.

5. The fungus which causes the Bermuda lily disease is identical with the Botrytis recently described as the cause of a similar disease in England.

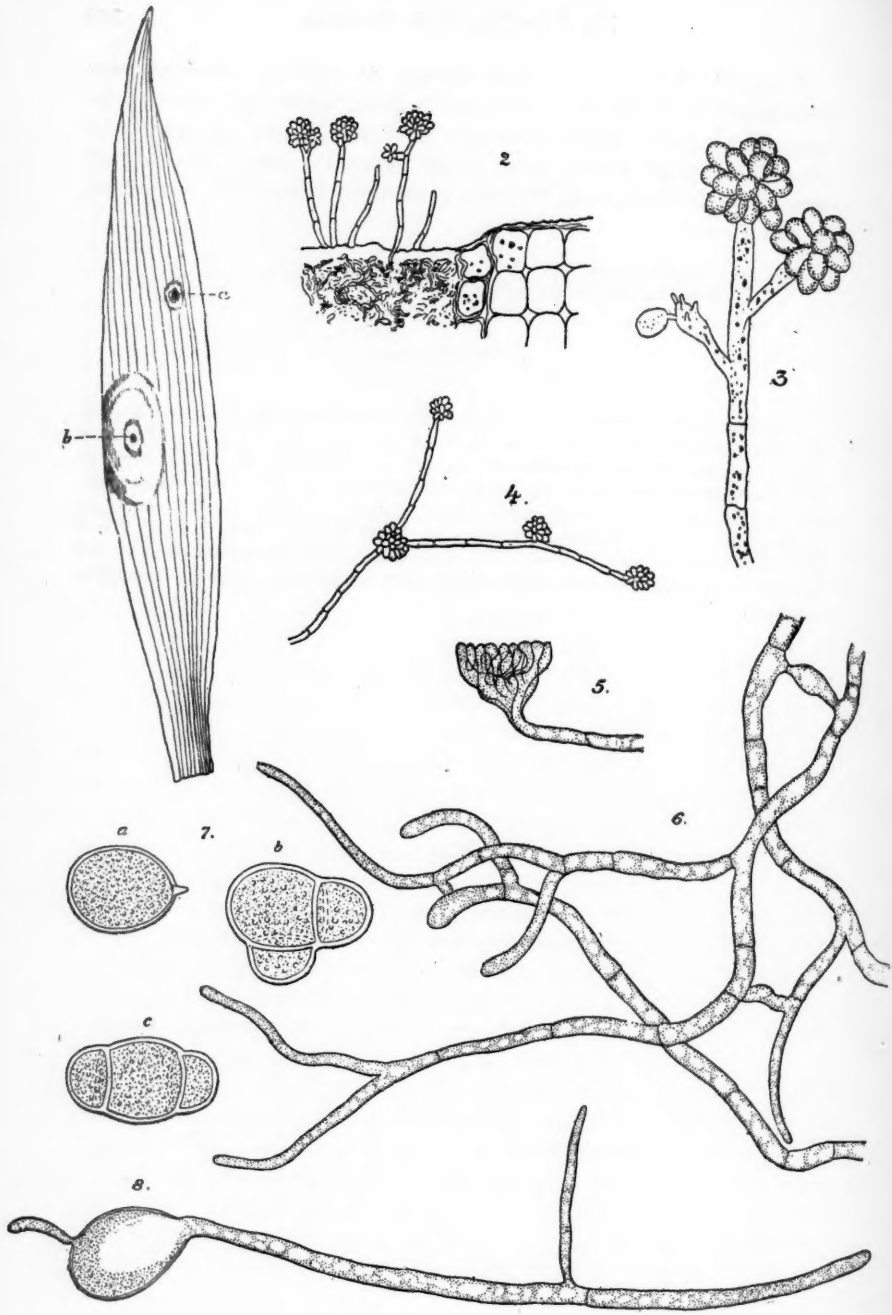
In making the investigation just described, it was hoped, not only to discover the cause of the disease, but also to suggest remedial measures. In this connection I may remark that the fungus itself seems to be delicate, so that its growth might probably be checked by almost any of the poisons used in the treatment of plant diseases, were it not for the difficulty of applying these effectively. Either a powder sprinkled on the leaves, or a liquid sprayed upon them, would here be ineffective, for the moisture would soon remove them, leaving the fungus free to grow. If, however, the fungus were present at the time of the application of the remedy, that part of it growing outside of the leaf might be killed, although that would not prevent the mycelium within the leaf from continuing to grow.

I have, however, observed that plants growing under the shelter of the oleander hedges are remarkably exempt from the disease. This I attributed at first to the drippings from the leaves, which I thought might partake of the acrid character of the sap of the oleander. I am inclined to believe, however, that it is rather because the lilies under the hedges are remarkably free from moisture. In fact, the overhanging hedge collects most of the dew, so that the dew-drops do not readily gather upon the leaves of the lily plants, and thus, perhaps, no opportunity is given for the growth of the fungus.

It might, therefore, be found feasible to grow, in alternate rows with the lilies, some other crop which, being higher and having more spreading foliage, should keep off the dew. A row of stakes with branches wattled among them might serve the same purpose and check the virulence, even if it did not entirely prevent the recurrence, of the disease.

BIOLOGICAL LABORATORY,
Mass. Institute of Technology.

EXPLANATION OF PLATE. — Fig. 1. Upper side of a leaf, with two spots upon it, showing different stages of the disease; (*a*) an early, and (*b*) a more advanced stage. — Fig. 2. A section through a diseased spot when the disease is far advanced. The hyphæ occupy all the tissue in the diseased area. — Fig. 3. A gonidiophore with its gonidia, showing the sterigmata and the attachment of the gonidia. — Fig. 4. A series of bunches of gonidia on an old gonidiophore. — Fig. 5. An organ of attachment. (After Marshall Ward.) — Fig. 6. Part of a mycelium showing cross branches. — Fig. 7. Gonidia; (*a*) an ordinary gonidium; (*b*) and (*c*) forms frequently assumed by gonidia shortly before germination. — Fig. 8. A sprouting gonidium.


a
b
2
3
4
5
6
7
a
b
c
8

THE DRY ASSAY OF TIN ORES.[1]

PART II.

BY HEINRICH O. HOFMAN, ASSISTANT PROFESSOR OF MINING AND METALLURGY.

Class A (b).

THIS class embraces the bronze assay of Winkler, and the different iron assays.

4. Winkler's method[2] is as follows: 5 grams of ore are mixed with 5 grams of cupric oxide and charged in a clay crucible; on top are placed 15 grams of black flux with 1.25 grams of borax glass, then a salt cover, and finally a large piece of charcoal. The crucible is heated in a muffle or a pot-furnace, after boiling has ceased, for three quarters of an hour to an hour at a bright red heat, finishing the assay at almost a white heat. The result is a white, brittle, tin-copper alloy. With every tin assay, an assay of 5 grams of cupric oxide with the same charge is made, and the weight of the resulting button of copper, subtracted from the bronze button, gives the weight of the tin contained in the ore.

This assay is really a modification of the German method. Its advantage is that no prills of tin (or, rather, particles of bronze) are found suspended in the slag. All the metallic oxides that have been reduced are found collected in one button. It is claimed that more tin is recovered by this method than by the regular German method, and that the buttons do not differ more than from 0.4 to 0.5 per cent. If this could be substantiated, the method would be a serious rival to the cyanide assay.

In the experiments carried out the directions given above were closely followed, only the black flux substitute (2 potassium carbonate and 1 flour) was used, as in the regular German method, instead of the black flux proper.

The charges were readily fusible, liquid, and showed a smooth surface when cool. The crucibles were not attacked, and no particles of bronze were discernible in the slags. As in the German assay, the

[1] Continued from Vol. III. No. 2, May, 1890.

[2] Berg- und Hüttenmännische Zeitung, 1864, p. 17; also Kerl, *op. cit.*, p. 483, and Balling, Die Probirkunde, p. 391.

upper salt slag and the lower borax slag have to be distinguished. The salt slag separates readily from the lower slag, has a crystalline structure, is brittle, has a pearly lustre, and is opaque. In the centre of every salt slag is a small cavity, into which white, fern-like crystals protrude. The white base of the crystals is encircled by a green-tinged shell, and this by the bulk of the slag, which is of a lighter purple color than that of the German assay. The reason is probably that less carbon is present in the charge, no charcoal having been added. The vitreous borax slag is hard, opaque, and greenish black. The oval bronze button is smooth, crystalline, brittle, white, and the more rounded copper button has thread-like lines of crystals on the surface, and is of a beautiful rose-color. Both separate well from their slags.

TABLE XVIII.

No. of Assay.	Resulting Bronze.	Resulting Copper.	Resulting Tin.	
	Grams.	Grams	Grams.	Per cent.
95	7.200	3.825	3.375	67.50
96	7.170	3.805	3.365	67.30
97	7.110	3.785	3.325	66.50
98	7.105	3.785	3.320	66.40
99	7.040	3.820	3.220	64.40
100	7.020	3.770	3.250	65.00
101	7.000	3.770	3.230	64.60
Average	7.092	3.794	3.298	65.96
102	7.185	3.920	3.265	65.30
103	7.140	3.920	3.220	64.40
Average	7.162	3.920	2.2425	64.85

Table XVIII. shows that too much has been claimed for this method, both as to output of tin and accuracy of results. The total average, Nos. 95 to 101 (65.96 per cent tin), is 1.88 per cent too low, and while in some cases excellent results are obtained (Nos. 95

and 96), in others, under the same conditions, an assay can be 3.24 per cent too low. It was thought that perhaps, by increasing the amount of reducing agent, better results could be obtained. Thus, 1 gram of charcoal was mixed with the 5 grams of ore and 5 grams of cupric oxide, and then the usual charge given. The results (Nos. 102 and 103) show only an increase of weight in the copper recovered. Chalk-lined crucibles were tried, as in the German method. But, while no essential particular could be observed in which the assay differed from that in the naked crucible, the results given in Table XIX. show that the discrepancy in the resulting weights of tin is enormous, while the output of copper is higher, and very even.

TABLE XIX.

No. of Assay	Resulting Bronze.	Resulting Copper.	Resulting Tin.	
	Grams.	Grams.	Grams.	Per cent.
104	6.850	3.815	3.035	60.70
105	6.660	3.815	2.845	56.90
106	6.760	3.810	2.950	59.00
107	6.250	3.810	2.440	48.80

As a modification, therefore, the chalk-lined crucible must here also be left out of consideration.

The reason that the results with the Winkler method vary so much is that the presence of copper adds a new difficulty to the assay. This can be seen from the tabulated results obtained in reducing cupric oxide for the tin assays carried out above.

In all the assays, precipitated, chemically pure cupric oxide was used. If reduced completely, 5 grams of cupric oxide ought to give 3.993 grams of copper. In the naked crucible we obtain as an average 3.801 grams, and a discrepancy of 0.055 gram between the highest and lowest results, which, if expressed in percentage, gives 1.1 per cent difference. In the chalk-lined crucible there is a better output in copper; if extra reducing agents be added a still better result is obtained, even in the naked crucible, but not a correspondingly better reduction of stannic oxide. It would seem, therefore, that the amount of tin reduced will vary according to the amount of copper carried off in the slag.

TABLE XX.

Grams of Copper resulting in Naked Crucible with Regular Charge.	Grams of Copper resulting in Naked Crucible with Regular Charge and one Gram Charcoal.	Grams of Copper resulting in Chalk-lined Crucible with Regular Charge.
3.825	3.920	3.815
3.820	....	3.810
3.805	....	....
3.785	....	....
3.770	....	....
Aver. 3.801	3 920	3.8125

In the assays with potassium cyanide it was seen that the presence of sulphates had a very bad effect on the result. As copper has a very great affinity for sulphur, the results of this bronze assay may also have been influenced by it. Several assays were made, omitting the salt and increasing the amount of potassium carbonate. The weight of the copper buttons was slightly higher, e. g. 3.850 grams; but the reduction of the tin was very imperfect, as it did not all alloy with the copper and collect in one button of bronze; prills of bright, malleable tin were found in the slag, showing that, to obtain a slag of sufficient fluidity for all reduced metal to collect in one button, the addition of salt is necessary. By reference to the German assay it will be seen that the presence of salt containing sulphates does not produce the same bad effect on tin as in the cyanide assay.

The Winkler method is given in a modified way by Ricketts:[1] ore, 10 grams; cupric oxide, 10 grams; black flux substitute, 30 grams; argol, 2 grams; borax glass, 5 grams, — are well mixed, charged in a chalk-lined crucible, a salt cover and charcoal are added, and the charge heated gradually to a white heat for an hour. He advises separating tin and copper in the wet way. In this modified method it will be seen that an additional reducing agent, argol, has been added, and that flux and ore are intimately mixed. Winkler makes a point of not mixing ore and flux, as he wishes to avoid the strong

[1] Notes on Assaying, 1886, p. 89; quoting from Mitchell, Manual of Assaying, p. 411 (probably fourth edition, as it has been omitted in the fifth edition of 1881).

boiling of the charge, whereby particles of alloy might adhere to the sides of the crucible and escape being collected in the button.

Three bronze assays were carried out and one copper assay, giving the following results.

TABLE XXI.

No. of Assay.	Resulting Bronze.	Resulting Copper.	Resulting Tin.	
	Grams.	Grams	Grams.	Per cent.
108	13.685	7.360	6.325	63.25
109	13.660	7.360	6.300	63.00
110	13.630	7.360	6.270	62.70
Average	13.658	7.360	6.298	62.98

They show no advantage over Winkler's original method. Less tin is recovered and more copper is scorified, and a treatment of the alloy in the wet way would be apparently a loss of time.

5. *Iron Assays.* — Two sets of assays were made, the one recommended by Ricketts,[1] for tin ores containing silica only, the other by Mitchell,[2] for ores containing silica and for tin slags.

The method is based on the fact discovered by Berthier,[3] and already alluded to, namely, that iron completely precipitates tin from its combination with silica as metal, if added in sufficient quantity; if not, the stannic oxide is reduced only to stannous oxide, the iron itself being at the same time oxidized to ferrous oxide. Any excess of iron will alloy with the resulting metallic tin.

(1.) Ricketts gives the formula: ore, 10 grams; hematite, 3 to 8 grams; potassium cyanide, 40 grams; and says: "Mix and charge in a charcoal-lined crucible, cover with cyanide, and then with charcoal, lute and heat strongly from one half to one hour, remove, tap carefully, cool, and break. If the tin be in small buttons, collect by washing with water to separate the charcoal, dry, and weigh. Treat the button as an alloy of tin and iron."

The result of the experiment was a porous, grayish-black slag, through which small buttons of alloy were finely disseminated, and

[1] Notes on Assaying, 1886, p. 89.
[2] Manual of Assaying, 1881, p. 483.
[3] Traité des Essais, 1847, Vol II pp. 459, 460, 484.

in the bottom of the crucible a button. Button and larger prills were picked out, the crucible lining crushed, the pulp screened, the scales and the siftings obtained from panning the pulp weighed with button and larger prills. The weights of the alloys were 8.355 and 8.320 grams, which shows a close agreement, if the amount of iron is the same in both cases. This assay was not further pursued, as there are more simple methods for obtaining accurate results. The silica of ores "containing silica only" can be treated in a much more simple way. It can be removed by washing, and the pure black tin assayed with potassium cyanide, or, if too great a loss of cassiterite is feared, the silica can be removed by hydrofluoric acid, and the resulting pure black tin then assayed. This method of assay has therefore little value for the assayer, except that it substantiates an interesting fact, namely, that iron carries down all the tin.

(2.) Mitchell[1] mixes 400 grains of ore with 200 grains of ferric oxide, 100 grains of fluorspar, and 100 grains of charcoal powder, charges the mixture in a covered crucible, keeps it at a dull red heat for half an hour, and then at a white heat for another half-hour.

In the experiments the above quantities were reduced to a basis of 10 grams of ore. These resulted in a hard, rough, bluish-black shell, with bronze-colored stains. The inside was filled with fine charcoal, no button or any prills being visible. Apparently the ore and the hematite had united to form a slag. The method was not further investigated. If tin slags are to be assayed, it is a simple matter to decompose the finely pulverized slag with sodium or potassium disulphate and then treat with acidulated water, when stannic oxide and silica will be left. The tin in this mixture can then be readily determined.

(3.) One more experiment remains to be mentioned here, i. e. the fusing of black tin with potassium ferrocyanide and potassium cyanide. Bloxam[2] states that by using this reagent all the tin can be obtained as an alloy. The idea that led to the experiments was, that, if a weighed amount of dried ferrocyanide were fused with the ore, the buttons obtained from a number of assays would all have the same weight. If all the iron set free by the decomposition of the ferrocyanide alloyed with the tin, the percentage of tin could be readily calculated.

In the experiments, 5 grams of ore were mixed with 5 grams of dried potassium ferrocyanide and 5 grams of potassium cyanide. For

[1] Manual of Assaying, 1881, p. 484.

[2] Journal of the Chemical Society, New Series, Vol. III., 1865.

the bottom of the crucible and for the cover 5 grams of potassium cyanide were reserved. The results of the experiments were negative. The alloy was partly disseminated through the lower gray slag, which was porous and tough, and had partly collected in a button. The weights of several 5-gram assays did not agree within 1 gram, showing that all the iron of the ferrocyanide had not united with the tin, but that part had remained suspended in the lower slag.

Class B.

The second group of assays comprises the Cornish methods, which are only for determining the tin obtained by treating the ores on a large scale. That the results of such assays must be wrong is conceded. How closely they may agree when repeated in the same way by the same person is not stated.

6. Mitchell[1] and Ricketts[2] give the following method "for pure tin oxide": 400 grains (Mitchell) or 10 grams (Ricketts) are placed in a charcoal-lined crucible, to which a cover is luted. The crucible is heated gradually for twenty-five minutes, finishing the operation at a white heat.

For the experiments, 25 grams of ore were treated as described. There resulted, in the bottom of the crucible, a dull button of tin, while on the walls and bottom were numberless bright prills of tin. Button and prills were free from iron. The charcoal lining was pulverized and made to pass a 60-mesh sieve. The button, the scales on the sieve, and the siftings resulting from the pulp that had been panned were weighed together. The weights of two assays were: —

18.120 grams = 72.5 per cent tin.
16.150 " = 64.6 " "

The chemical analysis shows only 67.84 per cent of tin. The reason for this strange result is to be sought in the panning of the fine pulp. When all the charcoal has been washed off there remains in the pan a heavy, black residue. It is almost impossible to see what part of this is fine tin and what heavy slag, as they scarcely differ in appearance. It is certain that with the result 72.5 per cent slag still remained with the tin, and it is not at all sure that it was all removed with the result 64.7 per cent. Perhaps after long acquaintance with uniform ores some approximately reliable estimates might be obtained, but as far as exact results go the method appears to the writer a very doubtful one.

[1] *Op. cit*, p. 480. [2] *Op. cit.*, p. 88.

7. Another method is given by Mitchell[1]: 2 ounces of ore are mixed with a small quantity of culm and projected into a red-hot, naked crucible; some fluorspar is added if necessary, and after a quarter of an hour's fusion the tin is poured. The prills in the slag are recovered by pounding and vanning.

In the experiments, 50 grams of ore were mixed with 12 grams of finely pulverized anthracite, shot into the red-hot crucible and heated for half an hour, a little fluorspar having been added. No fusion was apparent. The crucible was removed, and broken when cold. It contained a black, porous, fritted mass, full of prills of tin, and on the bottom a button. The entire lower part of the crucible was crushed, screened, and panned, and all the recovered tin weighed together. The weights were: —

34 10 grams = 68.20 per cent tin.
27 38 " = 54.70 " "

The same difficulty as above in separating the heavy, black slag from the fine tin causes the irregularity.

8. In connection with the Cornish methods it may be mentioned here that it has been the writer's custom, in melting out metallic tin from different grades of black tin, to mix the black tin with 5 per cent of lime, 5 per cent of fluorspar, and 12 to 15 per cent of charcoal or anthracite, the latter requiring a higher temperature but giving cleaner slags. With pure concentrates obtained from ore occurring in quartz no special difficulties have been encountered, so that the entire contents of a plumbago crucible weighing about 10 pounds can be readily poured. With impure concentrates the results of such fusions have always been somewhat pasty slags, and additions of lime or fluorspar were never of much avail. The only remedy has been to add salt, which makes the slags less pasty. The main point in all these fusions is always to have the crucible nearly filled. If the first charge has begun to fuse, a second one is added. Such a fusion takes from one to two hours. Unfortunately, no records have been kept of the amount of white tin contained in the black, which would give the amounts saved.

In reviewing the preceding experiments, it is striking that so many different methods and modifications should still be recommended when a few simple ones are quite sufficient. The experiments made show clearly that there are only two methods giving entirely satisfactory results. These are the German method, as exemplified by assays

[1] *Op. cit.*, pp 480 and 481.

Nos. 1 to 6, and the method of fusion with potassium cyanide, as from assays Nos. 35 to 38; or, still better, if sufficient material is available, Nos. 39 to 42.

In the following investigations concerning the influence the different minerals associated with the black tin have on the results of these assays, we shall see to which of the two methods the final preference is to be awarded.

V. Influence of Associated Minerals on the Assay.

The minerals that are liable to remain with the black tin after the ore has been washed, roasted, and treated with nitro-hydrochloric acid, are quartz, feldspar, mica, tourmaline, garnet, and columbite (tantalite). To test their influence, the minerals were ground fine enough to pass through a 60-mesh sieve, and any particles of iron coming from the implements used in grinding were removed by the magnet. The minerals were mixed with the black tin in the different proportions shown in the subjoined tables, and the effects studied which they have on the two best methods of assay, — the German method and the method of fusing with potassium cyanide. The charges were so regulated that the flux in the German assay was always equal to three times the quantity of the ore plus the mineral, and in the cyanide assay to six times the quantity. Four parts of cyanide were mixed with the ore; one part served as bottom for the crucible and one part as cover. In the German assay, the amount of borax glass was increased in proportion to the percentage of mineral added and that of salt decreased. The fusions were made in the usual way; the time for the cyanide assay had to be increased to not less than fifteen minutes before a tranquil fusion was obtained.

(1.) The quartz used was the ordinary compact, colorless variety.

The amount of soft slag found on top of the borax slag decreased in proportion to the percentage of quartz added, showing that part of it had entered into combination with the borax slag. In assay No. 111 it was ¼ inch thick, in No. 115 only ⅛ inch. Its structure was not so coarsely crystalline as usual. It grew finer, and the brittle slag became harder with increase of silica; the lustre remained the same; the color varied from gray to bluish-black. The borax slags increased in quantity as quartz was added, their vitreous character being somewhat impaired by the silica, and also their brittleness; the lustre remained uniform; the usual olive-green color changed somewhat and became brownish. The buttons separated well from their slags, had the usual appearance, and

were free from iron. The results obtained in Nos. 111 to 115 showed a gradual decrease in the amount of tin recovered. This is, however, less than has been generally supposed from the figures of Berthier, Nos. 116 to 120, which are usually quoted.[1] Berthier,[2] as the writer understands it, mixes his siliceous ore with four times the amount of black flux. With the German method of charging, the black tin with

TABLE XXII.

No. of Assay.	Charge.							Resulting Tin.	
	Ore.	Quartz.		Charcoal.	Bl. Flux Substitute.	Borax Glass.	Potass. Cyanide.		
	Grams.	Grams.	Per cent.	Grams.	Grams.	Grams.	Grams.	Grams.	Per cent.
111	5	1	16.66	1	18	1	....	3.280	65.60
112	5	2	28.57	1	21	1	....	3.100	62.00
113	5	3	37.50	1	24	....	....	3.035	60.70
114	5	4	44.44	1	27	....	....	2.945	58.90
115	5	5	50.00	1	30	....	....	2.565	51.30
					Bl. Flux.				
116	10	2.5	20.00	....	50	....	....	5.2	52.00
117	10	6.6	40.00	....	66.4	....	....	4.3	43.00
118	10	10.0	50.00	....	80	....	....	2.8	28.00
119	10	15.0	60.00	....	100	....	....	1.0	10.00
120	10	30 0	75.00	....	160	....	....	0.0	00.00
121	5	1	16.66	....	....	....	24	3.285	65.70
122	5	2	28.57	....	....	....	28	3.215	64.30
123	5	3	37.50	....	....	....	32	3.195	63.90

67.84 per cent of tin mixed with 50 per cent of silica gave 51.30 per cent of metallic tin; Berthier's black tin containing 70 per cent of tin, with the same addition of silica, but mixed with the flux, gave only 28 per cent of tin or 24.8 per cent less than is charged as in the German method. This shows the disadvantage of mixing ore with basic flux.

[1] Mitchell, *op. cit.*, p. 483; Ricketts, *op. cit.*, p. 87.
[2] Traité des Essais, 1847, Vol. II. p. 485.

In the cyanide assays, Nos. 121 to 123, the slags showed uniformly a very coarsely crystalline structure, and had a strong lustre. They were as opaque as usual, and became harder with the increase of silica. In No. 121 only the upper rim was parrot-green. This spreads in No. 122 so as to cover the entire surface; it is ¼ inch thick at the circumference and ⅛ inch in the centre; in No. 123, the thickness is uniformly ¼ inch. The appearance of the buttons is the same as if no silica had been added. The results show a decrease in the amount of tin recovered, but the loss is not so great as with the German assay.

(2.) The feldspar used was the compact albite that occurs so generally in the tin lodes; it has a very perfect cleavage, shows a pearly to a silky lustre, and is white with a tinge of gray.

TABLE XXIII.

No. of Assay.	Charge.							Resulting Tin.		Resulting Alloy.	
	Ore.	Albite.		Charcoal.	Bl. Flux Substitute.	Borax Glass.	Potass. Cyanide.				
	Grms.	Grms.	Per cent.	Grms.	Grams.	Grams.	Grams.	Grams.	Per cent.	Grams.	Per cent.
124	5	1	16.66	1	18	1	....	....	....	3.475	69.50
125	5	2	28.57	1	21	1	....	....	....	3.265	65.20
126	5	3	37.50	1	24	1.25	....	....	....	3.010	60.20
127	5	4	44.44	1	27	1.50	....	....	....	2.680	53.60
128	5	5	50.00	1	30	2	....	....	....	3.615	52.30
129	5	1	16.66	....	....	....	24	3.285	65.70	....	....
130	5	2	28.57	....	....	....	28	3.275	65.50	....	....
131	5	3	37.50	....	....	....	32	3.265	65.30	....	....

Salt and borax slags of the German method, Nos. 124 to 128, are similar to those obtained when quartz was added to the ore. The buttons, however, are surrounded by a slag that is more stony than the borax slag above, and almost black. It adheres strongly to the buttons, and is liable to retain particles of metal. All the buttons were dark and dull; they were brittle, hard to cut, and contained iron, its presence being caused by the infusible character of the albite; the reduction was prolonged and the ferric oxide of the cassiterite reduced before fusion took place, and alloyed with the metallic tin resulting from the more readily reducible stannic oxide. By examining the results, Nos. 124 to

128, it will be seen that, although all the buttons are ferruginous, the weight of the last four buttons is too low, showing that tin had also entered the slag, not enough iron being present to precipitate all the tin. The slagging is assisted by the intimate contact of the refractory feldspar and the cassiterite. Owing to the character of the charge, stannic oxide, or even metallic tin, is liable to be slagged by the alkali carbonate, and stannous oxide by the silica.

The influence on potassium cyanide is seen by Nos. 129 to 131 of the table. The upper white slag of pure cyanide with cyanate adheres to a lower porous slag of greenish-gray color, which encloses the buttons. These are white, bright, malleable, easily cut, and free from iron. The amount of tin lost, even if 37.50 per cent of albite is added to the ore,

TABLE XXIV.

No. of Assay.	Charge.							Resulting Tin.		Resulting Alloy.	
	Ore.	Muscovite.		Charcoal.	Bl. Flux Substitute.	Borax Glass.	Potass. Cyanide.				
	Grms.	Grms.	Per cent.	Grms.	Grams.	Grams.	Grams.	Grams.	Per cent.	Grams	Per cent.
132	5	1	16.66	1	18	1	....	....	....	3.190	63.80
133	5	2	28.57	1	21	1	....	....	....	3.250	65.00
134	5	3	37.50	1	24	1.5	....	....	....	3.200	64.00
135	5	4	44.44	1	27	1.5	....	....	....	3.605	72.10
136	5	5	50.00	1	30	2	....	....	....	....	....
137	5	1	16.66	....	....	....	24	3.260	65.20	....	....
138	5	2	28.57	....	....	....	28	3.235	64.70	....	....
139	5	3	37.50	....	....	....	32	3.165	63.30	....	....

is only a little over 2 per cent. It is strange that there should be so little difference between the three assays which contain such varying amounts of albite. The only explanation seems to be, that, at the low temperature at which the assay is carried out, the feldspar is not decomposed, but remains suspended in the lower slag, which receives its greenish tinge from the iron of the cassiterite and its gray from the feldspar mixed with it. If the lower slag is boiled in water, it falls to pieces, leaving a residue that looks very much like the original pulverized albite after it has been moistened, except that it has a slight tinge of green, resulting from the iron.

(3.) The mica used was a pure white muscovite.

The general behavior of the assays according to the German method, Nos. 132 to 136, is the same as those with feldspar, the exception being that with 50 per cent of mica only an incomplete fusion could be obtained. In the bottom of the crucible was a porous, fritted, dark mass, no tin being visible; it was covered by a semifused, scoriaceous, spongy mass of a brown color. The buttons had the same appearance and properties as those from the feldspar mixture. The results show a greater loss of tin and a stronger reduction of iron than above, the reason being that muscovite is more refractory in the assay than albite.

In the assays with potassium cyanide, Nos. 137 to 139, the behavior of mica is similar to that of feldspar, the mica appearing also here more refractory.

TABLE XXV.

No. of Assay.	Charge.							Resulting Tin.		Resulting Alloy.	
	Ore.	Tourmaline.		Charcoal.	Bl. Flux Substitute.	Borax Glass.	Potass. Cyanide.				
	Grms.	Grms.	Per cent.	Grms.	Grams.	Grams.	Grams.	Grams.	Per cent.	Grams.	Per cent.
140	5	1	16.66	1	18	1	....	....	....	3.470	69.40
141	5	2	28.57	1	21	1	....	....	....	3.300	66.00
142	5	3	37.50	1	24	1.5	....	....	....	3.250	65.00
143	5	4	44.44	1	27	1.5	....	....	....	2.295	45.90
144	5	5	50.00	1	30	2	....	....	....	....	....
145	5	1	16.66	....	....	....	24	3.285	65.70	....	....
146	5	2	28.57	....	....	....	28	3.250	65.00	....	....
147	5	3	37.50	....	....	....	32	3 235	64.70	....	....

(4.) The tourmaline pulverized for the experiments was the large black crystal which occurs so often with the tin ore.

In the German method, Nos. 140 to 144, the upper crystalline slag is parrot-green, the lower slag is slightly vitreous, but quickly becomes stony with the increase of tourmaline. The buttons have all a gray surface; they are dull, brittle, hard to cut, and ferruginous. These properties increase with the addition of tourmaline. In assay No. 144 no complete fusion could be obtained, and no button or particles of alloy were visible in the porous, fritted, dark mass. The results show

a loss of tin increasing with the addition of tourmaline, and an increased amount of iron is taken up by the tin.

With potassium cyanide tourmaline has no effect that is essentially different from that of previous assays, as the slags show about the same appearance, and the buttons the same properties and nearly the same weight.

(5.) The garnet occurring in the tin deposits is the iron garnet (almandite). It has a brownish red to fine deep red color, and is very rich in iron. This appears in its high specific gravity, 4.149, and from the fact that, after being heated by itself in a crucible to a bright red heat, it shows magnetic properties. For the experiments transparent crystals of a fine deep red color were pulverized.

TABLE XXVI.

No. of Assay.	Charge.							Resulting Alloy.	
	Ore.	Garnet.		Charcoal.	Bl. Flux Substitute.	Borax Glass.	Potass. Cyanide		
	Grams.	Grams.	Per cent.	Grams.	Grams.	Grams.	Grams.	Grams.	Per cent.
148	5	1	16.66	1	18	....	....	3.685	73.70
149	5	2	28.57	1	21	....	....	3 720	74.40
150	5	3	37.50	1	24	....	....	3.695	73.90
151	5	4	44.44	1	27	....	....	3.930	78.60
152	5	5	50.00	1	30	....	....	4.125	82.50
153	5	1	16.66	....	....	....	24	3.365	67.30
154	5	2	28.57	....	....	....	28	3.435	68.70
155	5	3	37.50	....	....	....	32	3.490	69.89

From the table it will be seen that no borax was added to the charges of the German assay, Nos. 148 to 152, as the garnet with the addition of a small amouut of base (lime or alkali) forms a liquid slag. The salt slags were less crystalline than usual, but otherwise the same with the exception of the color, which varied from light to dark red. The borax slags lost their vitreous and brittle character by the addition of garnet, became stony and tough, and changed from subtranslucent to opaque. The color, a dull olive-green, became lighter, the last slag, No. 152, being peacock-green. The buttons were all a dull dark gray, hard to cut, brittle, and rich in iron. The weights

obtained in the first four assays, Nos. 148 to 151, are strikingly close. This would seem to show that about the same amount of iron had been present in all of them, forming an alloy of nearly the same composition, the rest of the iron having remained in the slag. The uniformly well melted charges and the beautiful manner in which the one-button separates from the slag above, show that, if tin is to be recovered from siliceous ore as an alloy, a basic silicate of iron is the best, because it gives up the necessary iron for the tin and also retains sufficient in combination to form with the alkali of the charge a readily fusible, brittle slag.

In the cyanide assays the compact, white upper slag decreases, and the porous, bluish-green lower slag increases as garnet is added to the charge. In No. 153 the proportions were half and half, in No. 155 one quarter white and three quarters gray. The buttons are all ferruginous and show the usual characteristics. The figures prove that, although iron has been taken up, tin has gone into the slag.

(6.) The columbite found with the tin ores has an iron-black color and a streak that varies from a very dark brown to a pure black. The pure mineral has the following composition[1]: —

	Per cent.
Ta_2O_5	18.20
Nb_2O_5	64.09
FeO	11.21
MnO	7.07
SnO_2	0.10
CaO	0.21
Total	100.88

The specific gravity varies between 5.89 and 6.12. The columbite used for the experiments contained a small proportion of albite.

In the German assays, Nos. 156 to 160, the salt slags were stony and dull; their color, at first a brownish-green, gradually lost the brown, and became finally parrot-green. The borax slags were vitreous, brittle, and had a resinous lustre, the color changing from a light to a dark olive-green. The buttons were all ferruginous; their color, at first a dark gray, became black. The results show that the amount of iron reduced increased with the percentage of columbite added to the charge. Also, that if tin ore containing columbite be treated on a large scale, the columbite will probably behave in a way similar to the wolframite of Cornwall ores, where the iron that alloys with the

[1] Trans. Am. Inst. Mining Engineers, Vol. XVII. p. 593.

tin is the principal cause of trouble, and not the tungsten of the mineral, which, according to Berthier,[1] may be present in considerable quantities.

In the experiments with potassium cyanide the upper slags showed the usual properties, the lower slags were very porous, slightly glassy, and had a dark blue-gray color. The porosity increased with the percentage of columbite added. The buttons were white, bright, malleable, easily cut, and contained very little iron; from their appearance they might have been supposed to be free from iron, until especially examined for this metal. If pure cassiterite and pure columbite are

TABLE XXVII.

No. of Assay.	Charge							Resulting Tin.		Resulting Alloy.	
	Ore.	Columbite.		Charcoal.	Bl. Flux Substitute.	Borax Glass.	Potass. Cyanide.				
	Grms.	Grms.	Per cent.	Grms.	Grams.	Grams.	Grams.	Grams.	Per cent.	Grams.	Per cent.
156	5	1	16.66	1	18	1	....	....	....	3.400	68.00
157	5	2	28.57	1	21	1	....	....	....	3.605	72.10
158	5	3	37.50	1	24	1.5	....	....	....	3.775	75.50
159	5	4	44.44	1	27	1.5	....	....	....	3.820	76.40
160	5	5	50.00	1	30	2	....	....	....	3.875	77.50
161	5	1	16.66	....	....	....	24	3.355	67.10	....	....
162	5	2	28.57	....	....	....	28	3.370	67.40	....	....
163	5	3	37.50	....	....	....	32	3.300	66.00	....	....

ground together and fused, thus intimately mixed, with potassium cyanide, the iron and manganese of the columbite combine with the tin, leaving a yellowish slag which contains the columbic and tantalic acids.[2]

By comparing the effect produced by the associated minerals in the two methods of assay, we see that the cyanide assay must be accorded the preference, although, if the amount of associated mineral be small, the German method will give entirely satisfactory results. In concentration works, where several assays have to be made daily, the question of cost must be considered, and the cheap German assay will probably

[1] Traité des Essais, 1847, Vol. II. p. 472.

[2] Drs. Carpenter and Headden, Trans. Am. Inst. Mining Engineers, Vol. XVII. p. 633.

be preferred to the more expensive one, especially if the assay is only made in order that the manager may know how pure his concentrates are. In questions connected with the buying and selling of ores or concentrates, the assay with potassium cyanide is better, because the associated minerals have comparatively little influence on it.

VI. Preparation of the Ore for the Assay.

It will be seen from the foregoing that the influence of the associated minerals on the result of the assay is very considerable. It becomes, therefore, necessary to have as pure a black tin as possible for the dry assay. When it is remembered that tin ores contain only from 0.75 to 3 per cent of cassiterite, their preparation for the assay is seen to be a very important part of the work.

The separation of the cassiterite from the gangue is universally accomplished by crushing and washing. The resulting concentrates are then purified by means which vary according to circumstances. From the great difference in specific gravity between the cassiterite (6.4 to 7.1) and the non-metallic associated minerals (not over 4.1), it would appear at first sight that the separation ought to be very easy, but this, for various reasons, is far from being the case. Special precautions are needed if the loss of black tin is to be reduced to a minimum. The metalliferous minerals have too great a specific gravity (e. g. arsenopyrite 6 to 6.4) to be removed by washing; roasting and acids have to be used. The columbite (tantalite), whose specific gravity varies from 5.89 to 6.12, remains finally with the black tin, as it is not attacked by ordinary acids at all.

The implements used in assay laboratories for pulverizing larger quantities of ore are a small hand-crusher and a pulverizing plate. The ore is usually crushed, sampled down, and then pulverized on the rubbing-plate or in a mortar. Experience has proved that the common method of grinding the whole sample to a uniform size is not suited to the tin ores of the Black Hills. The main reason for this is the preponderance of mica. Any one who has tried to pulverize mica, even if previously heated, will appreciate the difficulty. Happily, very little cassiterite occurs in the mica proper, which if ground for a short time only on the rubbing-plate will not show any black tin or other mineral. The pulverization must be carried on with the subsequent washing in view. The first rule in concentration is, that a good preliminary sizing should precede the separation by specific gravity. The second is, that the ore should be coarse to prevent loss in washing. The latter point

is strongly emphasized in the present case by the fact that the brittle cassiterite will be ground to a slime, while other minerals in the ore are only converted into sands. The writer's practice has been to screen while the ore is being pulverized, crushing and screening alternately with a graduated series of sieves, Nos. 20, 40, 60, and 80. The ore is crushed until all the minerals, with the exception of the mica, are fine enough to pass a 20-mesh sieve; the mica is then examined for any minerals adhering to it, and these are removed by grinding, and screened. The different screenings are now washed separately in the gold pan, and the tailings panned over. The concentrates obtained by the separate washings are put together, dried, and passed through a 60-mesh sieve, and the washing is repeated, the result being pure concentrates and tailings. These are panned over if any cassiterite appears.

The writer has done all his washing of tin ore in the gold-pan; but any other apparatus, be it the vanning shovel used in Cornwall, or the "Sichertrog" of the Saxon or Bohemian miner, will, with the necessary practice, give the same result. In panning, it is found very difficult to separate the cassiterite from the garnet without losing much tin, although there is a great difference in their specific gravities, viz. 6.4 to 7.1 and 4.1. It is almost impossible to effect a complete separation, as can be seen from the analysis of the average sample, where the insoluble residue, 9.39 per cent, is principally garnet. This is on account of the different way in which the minerals break. Dana[1] says that both cassiterite and garnet have an uneven, subconchoidal fracture, and that both are brittle; they also differ little in hardness (6 to 7 *vs.* 6.5 to 7.5). But the cassiterite crushes into splinters, and the garnet into a granular form. It is probably this difference that causes the difficulty in separating the two minerals; the preponderating particles of cassiterite form an irregular angular network, and prevent the heavy garnet from being carried off by the water with the other minerals that have a lower specific gravity. If garnets are present in any large quantities it will be necessary to adopt other means to remove them. Dana[2] says that all garnets, except ouvarovite, are decomposed with hydrochloric acid after ignition. That this may be complete, the mineral has to be ground very fine. It will be remembered that the black tin used for the experiments was roasted, chilled, and treated with nitro-hydrochloric acid, and the garnets were not entirely removed. If the garnet is decomposed, the removal of

[1] System of Mineralogy, 5th ed., New York, 1880, pp. 158 and 265.
[2] *Op. cit.*, p. 270.

the gelatinous silica, either by washing or by hydrofluoric acid, is simple.

The black tin obtained by washing still retains sulphides and arsenides. Berthier[1] recommended boiling with nitro-hydrochloric acid and burning off any sulphur that might have separated. Plattner[2] objects to this, as the sulphur would not all be eliminated. He reverses the process, roasting first and then treating with nitro-hydrochloric acid. Following Plattner, the black tin is roasted on a dish in a muffle, and, to assist the decomposition of the garnet, chilled in cold water after roasting; it is then boiled in a porcelain dish with nitro-hydrochloric acid, which will also remove particles of metallic iron coming from the implements used in grinding; when all the iron is dissolved, the solution is poured off, and any light particles washed away. If necessary, the concentrates can be transferred to a platinum dish and treated with hydrofluoric acid. This, however, will rarely be required.

The roasting seems to have a favorable effect on the cassiterite by making it more friable and more readily reducible. The unroasted cassiterite of the Black Hills is subtranslucent, brown to black, and very hard to pulverize the roasted mineral is opaque, of a more or less reddish brown, and easily pulverized. The change that takes place in the reducibility of the ore is shown by the following experiments.

TABLE XXVIII.

No. of Assay.	Name of Mine.	Per cent of Tin from Raw Ore.	Per cent of Tin from Roasted Ore.
168	Occidental	48.90	49.00
169	Glendale	65.30	65.60
170	First Find	65.30	65.80
171	Similias	75.00	75.00

The results show that in some cases (No. 171) no difference exists between raw and roasted concentrates, while in others it may amount to 0.5 per cent.

If the preliminary treatment of a tin ore is carried out in the manner described, there will be a minimum of loss in black tin.

[1] Traité des Essais, 1847, Vol. II. pp. 486, 487.

[2] Blowpipe Analysis, edited by Richter and translated by Cornwall, New York, 1885, p. 466.

VII. Conclusion.

From this examination of the different methods of assaying tin ores in the dry way, it becomes apparent that, if ordinary precautions are taken, the necessary treatment, including the preliminary preparation of the ore, is a comparatively simple matter; neither is the influence of the associated minerals so great, at least with the cyanide assay, as is generally supposed. Lastly, the results obtained show that the dry assay of purified black tin gives more accurate results than that of any other base metal, if the few correct methods, none of them requiring special skill, are followed and ordinary care is given to the work.